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First-Strike Stability and Strategic Defenses

Part II of a Methodology for Evaluating Strategic Forces

Glenn A. Kent, David E. Thaler

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PREFACE

All too often, advocates of particular views surrounding strategic forces have supported their advocacy in the name of "stability" without defining the relevant context or demonstrating that (1) stability is seriously endangered in the first place and (2) adopting their agenda would alleviate this problem. Alternatively, some dismiss stability as a basis for evaluating strategic forces.

The authors of this study and the study preceding it (*First-Strike Stability: A Methodology for Evaluating Strategic Forces*, R-3765-AF, August 1989) have chosen to foster a clear and comprehensive understanding of stability. In particular, they explore the effect of strategic defenses on *first-strike* stability, which they define as the condition that exists when neither superpower perceives the other as motivated by the posture of strategic forces to strike first in a crisis. This subject warrants careful examination as the United States contemplates far-reaching decisions regarding modernizing strategic forces as well as reducing these forces through arms control agreements.

Favorable developments in U.S.-Soviet relations have themselves contributed to stability in general: A severe crisis involving the United States and the USSR seems far less likely than it has in the past, and all can take comfort in the fact that serious consideration of the costs associated with a first strike is not apt to appear on the agenda of any meetings called by either of the leaders of the two superpowers. A better appreciation and understanding of first-strike stability can further these positive developments by encouraging enduring changes in the structures and postures of U.S. and Soviet strategic forces that will render the matter of first-strike stability moot.

A continuing effort to demonstrate a methodology for evaluating the merits of alternative postures of strategic forces has been conducted under the project entitled "Special Activities" in the National Security Strategies Program of Project AIR FORCE.

The study is addressed primarily to serious analysts concerned with strategic matters. It should also prove useful to policymakers in the administration, Congress, and the military services.

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SUMMARY

One of the most pressing issues facing the United States over the next few years centers on the question of whether, and for what strategic purposes, the United States should deploy nationwide ballistic missile defenses (BMD). One reason advanced is that such defenses could promote "deterrence" and enhance "stability." However, such claims are rarely, if ever, accompanied by analyses demonstrating that deterrence and stability constitute problems demanding attention and that deploying strategic defenses would alleviate any such problems if, indeed, they existed.

This report provides a methodology to evaluate alternative strategic offensive and defensive forces on the basis of first-strike stability. This methodology is demonstrated for offensive forces alone in *First-Strike Stability: A Methodology for Evaluating Strategic Forces*, R-3765-AF, August 1989. It is expanded to assess the effect on first-strike stability of low, intermediate, and high levels of BMD for two structures of strategic offensive forces: (1) current forces and (2) forces likely to be deployed under the emerging strategic arms reduction treaty (START).

We do not present this methodology as a vehicle for predicting the likelihood that a crisis might become unstable and lead to war. First-strike instability arises solely from the structure of strategic forces and the posture of forces within that structure. The much broader matter of crisis instability arises from numerous factors that might affect stability in a crisis, including psychological stress, ambiguous or incorrect information, erroneous assessments of enemy intent, miscalculation, and misperception. By this construction, first-strike instability is a component of crisis instability. This report treats only first-strike instability—the instability stemming from the posture of strategic forces.

First-strike stability between two adversaries is robust when both leaders perceive no great difference between the expected "cost" to each side of striking first and the expected "cost" of incurring a first strike if one withholds his attack. In such circumstances, neither superpower leader perceives himself (or his adversary) as pressured by the posture of forces to strike first in a deepening crisis. First-strike stability could become an important factor toward escalation if either leader (or both leaders) believed that the other perceived an advantage in going first.

Use of the methodology outlined in this report demonstrates that neither the United States nor the USSR currently can substantially limit retaliatory damage through a first strike on the other side's strategic offensive forces. However, an unconstrained competition in the deployment of strategic defenses could lead to a situation where one's first strike would overwhelm the defenses of the adversary, but not one's second strike. In such an environment, each country would be able to limit damage substantially in a first strike but not in a second, and thus first-strike stability is eroded. To avoid a marked decline in retaliatory capability, each nation would probably respond to the opponent's defense deployments by increasing its strategic offensive forces. Thus, the following conclusions are drawn:

- **First-strike stability is currently quite robust.**
- **Deployment of strategic nationwide ballistic missile defenses by either superpower in competition with the other's strategic offenses generally erodes first-strike stability.**
- **Enhancing first-strike stability cannot be the avowed reason for deploying strategic nationwide ballistic missile defenses.**
- **Neither country would be likely to continue to adhere to agreements that constrain and reduce offensive arms under the specter of intent by the other to deploy robust strategic defenses in contravention to the 1972 Anti-Ballistic Missile (ABM) Treaty.**

Applying the methodology also indicates that U.S. and Soviet strategic defenses with the capability to intercept 500 to 1000 reentry vehicles (RVs) and decoys would not greatly affect first-strike stability, even after reductions in offensive arms under START I. In the presence of such defenses, however, much deeper cuts in offensive arms would undermine stability. Furthermore, pronouncements in the public domain indicate that the "Phase I" deployment of U.S. strategic nationwide BMD contemplated by the Joint Chiefs of Staff would be capable of intercepting well over 1000 RVs. These higher levels of defenses could seriously erode first-strike stability. We conclude the following:

- **There may be a "window" in which U.S. and Soviet strategic nationwide BMD could be robust in defending against "limited" attacks (third-country ballistic missile attacks, unauthorized attacks, and accidental launches), yet not so robust that first-strike stability is seriously undermined.**

- The level of U.S. defenses attributed to the so-called "Phase I" deployment seems to go beyond the upper bounds of this "window" even with current offensive forces, and certainly with offensive forces constrained by START I.
- On the basis of first-strike stability, deployment of defenses capable of defending against third-country ballistic missile attacks, unauthorized attacks, and accidental launches (i.e., capable of intercepting up to 1000 RVs) would tend to preclude reductions in offensive forces much beyond START I levels.

Substantial and capable bomber forces on the two sides would prevent first-strike instability from becoming acute at levels of ballistic missile defense where a first strike could overwhelm the other side's defenses, but a ragged retaliatory attack with ballistic missiles could not. Even if none of the retaliator's RVs could penetrate the first-striker's defenses, neither side could avoid considerable damage when striking first if both had bomber forces capable of inflicting high levels of damage on the first-striker. This suggests that any attempt to transition to a situation in which each side's strategic defenses dominate the opponent's ballistic missiles must include a careful negotiation on the critical role of bomber forces in maintaining first-strike stability.

Finally, proposals to modernize, reduce, or alter the structure and posture of strategic offensive forces, as well as proposals to deploy strategic defenses, should be evaluated on the basis of first-strike stability. The methodology demonstrated in this report and its predecessor should be the means used to assess the effects of such proposals on first-strike stability.

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GLOSSARY

central deterrence—The objective of eliminating—by threatening retaliation (countervailing action) with U.S. strategic nuclear weapons—any temptations for a Soviet leader to launch a nuclear first strike against U.S. territory. In the context of deterrence, we assume each leader has an unambiguous choice between striking first and no war at all.

cost—A measure of (1) the damage suffered by one's own country and (2) the damage that a country fails to inflict on the enemy in attempting to keep him from achieving his war aims if war occurs.

counterforce attack—An attack by Country A against Country B's strategic nuclear forces, forces that Country B can direct against Country A in a retaliatory attack. The purpose of a counterforce attack is to limit damage to oneself; this applies especially to a first strike.

countervalue attack—An attack against the value structure of the enemy to deny the adversary his war aims; this applies equally to first or second strike (see value structure). Although many analysts use this term to describe an attack against cities, we contend that an attack against theater projection forces, war-supporting facilities, and possibly leadership in an effort to deny the adversary his war aims is an attack against the assets that the adversary values.

crisis instability—The condition that exists when either leader feels pressure because of emotion, uncertainty, miscalculation, misperception, or the posture of forces to strike first to avoid the worse consequence of incurring a first strike. In the context of crisis instability, we assume that neither national leader has an unambiguous choice between striking first and no war at all—i.e., if a leader waits, he does not know whether he will be avoiding war or incurring a first strike.

damage domain—A domain that portrays any combination of damage to U.S. value and Soviet value in a strategic nuclear exchange; it is used in deriving the cost function.

defense domain—A domain that depicts various combinations of U.S. and Soviet defense potential.

defense potential—The effectiveness of a given ballistic missile defense expressed in terms of the absolute number of reentry vehicles required to overwhelm that defense.

DGZ curve—A curve that expresses the percent of total value in the currency of *designated ground zeros*, or aimpoints (see value structure).

first-strike instability—The condition that exists when, owing to the posture of forces, either leader is perceived to feel pressure to strike first in a crisis to avoid the worse consequence of incurring a first strike. Enhancing first-strike stability eliminates force posture as a catalyst to crisis instability.

force posture—The state of generation and dispersal of strategic forces reflecting the portions of such forces that are targetable and nontargetable. Nontargetable forces include bombers on strip alert (with adequate warning), SSBNs at sea, dispersed mobile ICBMs, and silo-based ICBMs that can (in the attacker's eyes) be launched under attack.

force structure—The types and numbers of force elements (missiles, bombers, and submarines); the characteristics of those force elements (probability of kill, reliability, penetrability, and hardening); and the basing modes (mobility and redundancy).

generation of forces—The placement of forces in a nontargetable, and therefore survivable, posture (see force posture).

ICBM—Intercontinental ballistic missile.

index of first-strike stability—A numerical index for ranking structures and postures of strategic nuclear forces on the basis of first-strike stability.

leak rate—A measure of the design shortfalls inherent in a given defense system, expressed as the probability that a reentry vehicle that the system is supposed to detect, track, and engage will not be destroyed.

RV—Reentry vehicle.

SDI—Strategic Defense Initiative.

SLBM—Submarine-launched ballistic missile.

SSBN—Nuclear-powered ballistic missile submarine.

START—Strategic arms reduction talks.

value structure—The value structure used in this analysis includes the theater projection forces, war-supporting facilities, and leadership of each nation (see countervalue attack).

I. INTRODUCTION

As the 1990s begin, an important issue of national security seems far from being resolved: whether, and for what strategic purposes, the United States should deploy strategic nationwide ballistic missile defenses (BMD). The impetus for addressing this issue dates from 1983 when President Reagan announced an effort to explore the possibility of using defenses to render ballistic missiles "impotent and obsolete."¹ To support this effort, the Strategic Defense Initiative (SDI) was unveiled to conduct research and to develop potential architectures for defenses against ballistic missiles.

In launching the SDI effort, the President sought to make major strides toward achieving a worthy long-term strategic goal: placing the nation's survival under its own control. He hoped that the nation could eventually be made invulnerable not only to ballistic missile attack, but to other means of nuclear weapons delivery as well.

Since the President's initial speech, however, the goals set forth by advocates of deploying strategic nationwide ballistic missile defenses have become ambiguous and inconsistent. Supporters of deploying strategic nationwide BMD have made statements such as the following:

- "[T]he Strategic Defense Initiative is integral to the maintenance of stability both under a potential START [strategic arms reduction talks] agreement and in the absence of such an agreement."²
- "Strategic defenses will help to increase stability during the transition period as we are reducing further our nuclear missiles under START."³
- "A better way for maintaining strategic stability while preserving deterrence is for both sides to move gradually to a prudent mix of offensive and defensive systems."⁴
- "Providing partially effective protection against the entire range of targets the Soviets consider important should provide a more

¹President Ronald Reagan, "Address by the President to the Nation," March 23, 1983, Office of the Press Secretary, The White House, p. 9.

²"Report to the Congress on the Analysis of Alternative Strategic Nuclear Force Postures for the United States Under a Potential START Treaty," The White House, July 25, 1989, p. 5.

³*Ibid.*, p. 6.

⁴Zbigniew Brzezinski, "Entering the Age of Defense," *The Washington Post*, October 2, 1988, p. C2.

stable and cost-effective deterrent than adding new survivability features to a small number of offensive missile systems.”⁵

One purpose of this report is to assess the validity of these and similar statements. More broadly, this report offers a rigorous methodology for assessing the effect on first-strike stability of defensive system deployments or changes in offensive force structure and posture.

IMPORTANT DISTINCTIONS BETWEEN STABILITY AND DETERRENCE

Analysts of strategic matters often use the concepts of “stability” and “deterrence” interchangeably. This is understandable, since both concepts are intended as objectives supporting a fundamental U.S. goal of avoiding war, especially strategic nuclear war. However, we believe that the concepts of stability and deterrence should be treated separately.

The calculus of “central” deterrence considers whether a superpower leader might be *tempted* to execute a first strike against his opponent. In this context, the leader believes that his decision lies unambiguously between striking first and no war if he waits. Failure of deterrence occurs when that leader concludes that the “benefits” accruing from a nuclear first strike outweigh the benefits of peace. Given the current capability on the part of both superpowers to launch a substantial second strike, such a conclusion is not plausible.

The calculus of first-strike stability, by contrast, considers whether a leader in the midst of a deep superpower crisis might be *pressured*, by the posture of strategic forces, to execute a first strike against his opponent. First-strike stability explicitly addresses the more demanding case of a leader believing that his choice lies not between striking first and no war if he waits, but between striking first and possibly *incurring a first strike* if he waits. Thus, a leader might feel pressure to strike first to avoid the potentially worse consequence associated with striking second; i.e., he perceives that the “cost” to his nation of striking first might be much less than the potential “cost” of incurring a first strike if he waits.⁶

⁵Lt. Gen. James A. Abrahamson, “End of Tour” Report, quoted in *Aerospace Daily*, March 24, 1989, p. 472.

⁶In the context of this calculus, cost is measured in terms of the damage one incurs plus the damage one does not inflict on the adversary discounted by some factor. See below and Glenn A. Kent and David E. Thaler, *First-Strike Stability: A Methodology for Evaluating Strategic Forces*, The RAND Corporation, R-3765-AF, August 1989; and Glenn A. Kent, Randall J. DeValk, and David E. Thaler, *A Calculus of First-Strike*

We distinguish between first-strike instability and "crisis" instability. First-strike instability arises solely from the structure and the postures of strategic forces. The much broader matter of crisis instability arises from numerous factors that might induce instability in a crisis, including psychological stress, ambiguous or incorrect information, erroneous assessments of enemy intent, miscalculation, and misperception. By this construction, first-strike instability is one component of crisis instability.⁷

The methodology presented in this report treats only first-strike instability—instability stemming from the posture of strategic forces. It is not intended to address the more extensive subject of crisis instability. Accordingly, *this methodology is not a vehicle for predicting the likelihood of war given a crisis*. Rather, it indicates which postures of strategic forces are more likely to act as mitigators or as catalysts to instability in a deep crisis.

THREE STRATEGIC ENVIRONMENTS

At the national security level, there are generally three alternative environments to consider:

- An offense-dominant environment.
- A defense-dominant environment.
- An environment in which offense and defense compete for supremacy.

Understanding the conditions in each of these environments provides the basis for the discussion on strategic defenses. Figure 1 summarizes the discussion.

In the current offense-dominant environment, the superpowers have large inventories of strategic nuclear weapons, and strategic defenses are constrained to near zero by the 1972 Anti-Ballistic Missile (ABM) Treaty. First-strike stability is fairly high owing to robust retaliatory capabilities on both sides as long as each nation maintains adequately survivable postures of offensive forces. Neither leader is likely to be pressured or to perceive the other as being pressured by the posture of forces to strike first to avoid the potentially worse consequence of incurring a first strike. Also, no Soviet leader would be tempted to strike the United States: The U.S. posture of forces provides central

Stability (A Criterion for Evaluating Strategic Forces), The RAND Corporation, N-2526-AF, June 1988.

⁷See the Glossary for definitions of force structure and force posture.

Issues		Strategic Environment		
		Offense-Dominant	Defense-Dominant	Offense-Defense Competitive
Strategic Forces	Offensive	Large	Near-zero	Large
	Defensive	Near-zero	Large	Large
National Security Objectives	First-Strike Stability	<i>Robust</i> since both devastated no matter who strikes first	<i>Robust</i> since both survive no matter who strikes first	<i>Eroded</i> since survival may be conditional on striking first
	Central Deterrence	<i>Provided</i> by devastating U.S. retaliatory capability	<i>Replaced</i> by denial	<i>May not be provided</i> since threat of devastating retaliation may not be credible
Control of National Survival		Under adversary's control	Under own control	Conditionally under own control

Fig. 1—Strategic forces, national security objectives, and control of national survival in three strategic environments

deterrence by offering a retaliatory capability that would cause "unacceptable" damage to the Soviets' value structure.

As shown in Fig. 1, a defense-dominant environment also is characterized by a robust first-strike stability. In this environment, very capable ballistic missile and air defenses are accompanied by extremely low levels of strategic offensive forces. In these circumstances, each leader can substantially limit damage to his nation's value even if his country incurs a first strike. Hence, there is little difference to either side between striking first and striking second. In this environment, each country denies the enemy the prospect of destroying its value structure; the objective of deterrence—underwritten by the capability to threaten retaliation, or countervailing action, against the opponent's valued assets—thus becomes moot.

We can more fundamentally describe the difference between offense-dominant and defense-dominant environments in terms of who controls each side's national survival. Today, U.S. national survival rests in the hands of Soviet leaders; similarly, Soviet national survival is under U.S. control. Neither side can prevent the other from unleashing devastating destruction on the assets it values, regardless of

who strikes first. Conversely, in a defense-dominant environment, each country controls its own national survival. Each can limit damage to a considerable degree regardless of who strikes first, and hence survival is assured.

In an environment in which offense and defense coexist, each country still could devastate the other if it struck first; however, each country might be able to limit damage to itself by striking first through the combined effects of counterforce (attacking the opponent's nuclear retaliatory forces) and defense. Thus, one's survival is conditionally under one's own control; i.e., survival depends on one's striking first. In this environment, each leader might perceive the opponent as pressured to strike first and himself feel pressure to preempt, a situation in which first-strike instability might become acute.

STUDY APPROACH

In R-3765-AF, *First-Strike Stability: A Methodology for Evaluating Strategic Forces* (hereafter referred to as *Part I*), we introduced a model for assessing alternative postures of U.S. and Soviet strategic offensive forces on the basis of first-strike stability. In this study, we extend this methodology to gauge relative first-strike stability when strategic offensive forces interact in the presence of varying levels of strategic nationwide ballistic missile defenses. The study does not present an exhaustive treatment of alternative structures and postures of strategic forces. Rather, it offers a methodology for analysts to use in evaluating proposals for modernizing U.S. strategic offensive forces and for deploying strategic defenses.

Section II sets forth a concept of "cost" given a nuclear exchange, and it defines how to measure this "cost." Section III describes the effect of strategic nationwide ballistic missile defenses on damage to each side's value structure. In Sec. IV, we apply the methodology to evaluate how the presence of strategic defenses affects first-strike stability. Finally, in Sec. V we offer some concluding remarks.

Appendix A contains the U.S. and Soviet strategic offensive force structures and postures used in this study. Appendix B provides an analysis of alternative modes for operating strategic nationwide ballistic missile defenses. This analysis constitutes the basis for many of the calculations in this study. In App. C, we discuss the relationship between weapons available to attack high-value assets and the damage to those assets. Appendix D provides an excursion in which all U.S. bombers are deemed vulnerable in a Soviet first strike.

II. DEFINING AND MEASURING COST

DEFINITION OF COST

Any definition of cost must incorporate each nation's objectives in the context of a nuclear war. Given a strategic nuclear exchange, a country has two overarching objectives: (1) limit damage to its own value structure to the extent possible and (2) deny enemy war aims by inflicting damage on the adversary's value structure. In an attempt to limit damage to one's own value structure, one launches a counterforce attack against the enemy's strategic retaliatory forces. To inflict damage on the value structure of the enemy, one launches a countervalue attack against that target set. Strategic defenses potentially interfere with the counterforce and countervalue attacks and render these attacks less effective.

In this study, the value structure of each side consists of its theater projection forces (army, navy, and air forces), its war-supporting facilities (but not war-supporting *industry* tied to cities), and its leadership.¹ In our vernacular, a countervalue attack does not correspond to the devastation of cities.

How each side uses its offense and its defense is complicated by the fact that *limiting damage and inflicting damage are objectives in tension*—e.g., a weapon allocated against an enemy ICBM silo to limit damage means one less weapon that can be allocated against an enemy army garrison, airfield, ammunition depot, etc. to inflict damage. Thus, minimizing cost involves the process of finding the optimal tradeoff between limiting damage to one's own value and inflicting damage on the adversary's value.

THE COST FUNCTION

Cost in its simplest form is the damage a country incurs plus some measure of the damage *not* inflicted on the opponent. We write the cost function as follows:

$$C_{\text{self}} = D_{\text{self}}^x + \lambda(1 - D_{\text{enemy}}^y),$$

where C is cost and D is the fraction of value destroyed (i.e., damage is less than or equal to 1.0). We take $\lambda = 0.3$ and $x = y = 0.75$. The term

¹See Part I, pp. 7-8; and Kent, DeValk, and Thaler, 1988, p. 6.

λ is a discount factor that accounts for the much greater importance invariably attached to limiting damage to one's own country. The exponents x and y capture the idea that a leader places greater emphasis on limiting than on inflicting damage when damage to his nation's value is low and that to the enemy's value is already high, than when the reverse is true.

The methodology adapts to varying views concerning the relative importance of limiting versus inflicting damage. Most important, different assumptions as to the values of the discount factor and the exponents have little effect on the stability index and never alter the relative stability of alternative postures of forces.²

The cost function is a necessary basis for choosing between conducting attacks on the adversary's strategic nuclear retaliatory forces and on the opponent's value, or for choosing between defending one's own retaliatory forces and defending one's own value. In fact, without an explicit cost function, there is little analytic basis for allocating offensive forces between counterforce and countervalue attack or for choosing the best strategy for operating one's defenses.

²The accuracy of these statements is not intuitively obvious. The cost function is derived to make a set of curves behave in a "damage domain" according to one's own attitudes (see "damage domain" in the Glossary). For additional detail, see Part I, pp. 11-17. For a sensitivity analysis, see App. C in the same document.

III. PORTRAYING THE EFFECT OF STRATEGIC NATIONWIDE BMD

This section discusses how we portray the effect of various levels of strategic nationwide BMD. To set the stage for the analysis that follows, we offer some basic concepts as to how strategic defenses operate and how this methodology portrays their effectiveness.

BASIC CONCEPTS

Operating Modes

The central function of ballistic missile defenses is to subtract reentry vehicles (RVs) out of an attack. Generally, there are five modes in which a BMD system might be operated to carry out this function. These modes offer varied effectiveness in terms of specific targets surviving an offensive attack.¹ The five modes are as follows:

- Preallocated preferential BMD where the defender assumes that the attacker knows the level of defenses at any particular target, and where the defender cannot change this level once the attack has commenced. In this circumstance, the defender has no choice but to defend each target uniformly and the concept of preferential defense becomes moot.
- Preallocated preferential BMD where the defender assumes that the attacker does not know the level of defenses at any particular target and where, as in the first mode, the defender cannot change this level once the attack has commenced.
- Random subtractive BMD where the defense does not preferentially defend any particular target or intercept any particular ballistic missile.
- Adaptive preferential BMD where the defense adapts to the attack as it unfolds and preferentially defends the most lightly attacked targets.
- Defenses that can discriminate among types of missiles on the basis of the silo from which they were launched and

¹See Glenn A. Kent and Randall J. DeValk, *Strategic Defenses and the Transition to Assured Survival*, The RAND Corporation, R-3369-AF, October 1986. For a treatment of some of these defense modes, see App. B below.

preferentially intercept certain types of ballistic missiles and their warheads—e.g., those missiles carrying RVs capable of destroying hardened targets.

In this study, we assume that defenses are operated in a random subtractive mode according to the analysis in App. B.

Describing the Effectiveness of Defenses

In the methodology of this study, *the effectiveness of ballistic missile defenses is expressed in terms of two measures: (1) the absolute number of RVs required to overwhelm the defenses and (2) the inherent leak rate of the defense system.* Describing defenses according to the absolute number of RVs required to overwhelm the defenses differs markedly from describing them only in terms of the percent of RVs removed from an unspecified attack. In the latter case, for instance, a defense might be portrayed as “60 percent effective.” In practice, this might mean that a defense had the capability to subtract 60 percent out of an attack of 1000 RVs, but only 6 percent from an attack of 10,000 RVs. We believe that the absolute number of RVs required to overwhelm the defense is a more logical expression of the effectiveness of a given defense. The defenses potentially could remove all RVs from the attack up to the overwhelm point—in this case, 600. Such a defense is said to have a “defense potential” of 600.

We also describe defenses generally as a function of a given country's total arsenal of ballistic missile RVs. For example, a U.S. defense potential of 1000 is said to constitute a *low* level of defense against some 10,000 RVs in the current Soviet inventory. An *intermediate* level of defense would be a potential equaling about half that inventory—i.e., some 5000. We describe a defense as *high* if its potential equaled or exceeded the number of RVs in the inventory; when that inventory is changed, however, these modifiers reflect different absolute levels of defense potential. While a defense potential of 5000 is “intermediate” against current Soviet ballistic missile forces, it would be “high” against Soviet forces reduced and constrained by START.

The inherent leak rate, the second measure by which defenses are described, accounts for the design shortfalls inherent in any defense system. The inherent leak rate defines the probability that an RV that the defense system is supposed to detect, track, and engage will not be destroyed.² Thus, if a system has a leak rate of 10 percent and its

²Contrary to some conceptions, the leak rate of a system does not refer to the number of RVs penetrating the defense after the defense has been overwhelmed (saturated)—i.e., the total number of attacking RVs less the defense potential.

defense potential equals the total number of attacking RVs, 10 percent of the attacking RVs will "leak" through the defense.

We assume a leak rate of 10 percent. Varying that would not affect the basic methodology and would have a minimal effect on any results.³

CALCULATING THE EFFECT OF STRATEGIC DEFENSES

Relating the Number of Penetrating RVs to Defense Potential

Figure 2 depicts the number of penetrating Soviet RVs as a function of U.S. defense potential for various levels of Soviet attack.

As U.S. defense potential increases from zero to equal the number of attacking RVs, the number of Soviet RVs that penetrate falls linearly. To calculate the probability of penetration (P_p) of a particular RV when the number of attacking RVs equals or exceeds the defense

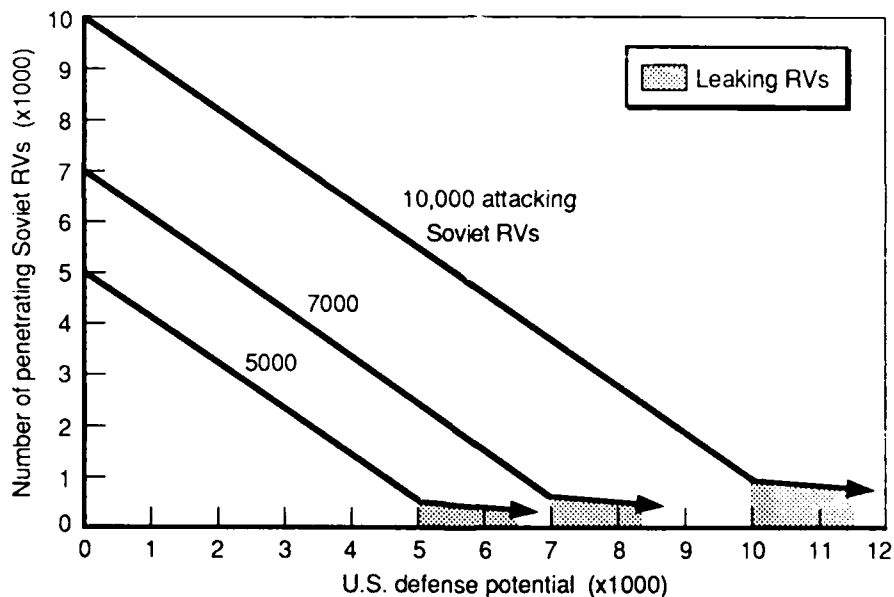


Fig. 2—Describing RV penetrability in the presence of strategic nationwide ballistic missile defenses

³The assumption of a 10 percent leak rate is not intended to reflect a belief that such a low leak rate could indeed be achieved.

potential, we use the equation

$$P_p = \frac{(A - D + \theta D)}{A},$$

where A is the total number of attacking RVs, D is the defense potential, and θ is the leak rate. For example, given a leak rate of 10 percent and a total attack of 5000 Soviet RVs, a U.S. defense potential of 1000 would yield $P_p = 0.82$.

Until the defense potential equals the total number of RVs in the attack, RVs will penetrate the defense both because (1) the attack saturates the BMD system and (2) the BMD system has an inherent leak rate. When the defense potential equals or surpasses the total number of RVs, only "leaking" RVs penetrate. Thus, we find breaks in the lines in Fig. 2 at points where the defense potential equals the total number of attacking RVs.

As the defense potential increases further beyond the total number of RVs in the attack, a defense can reduce the leak rate inherent in the BMD system through two-on-one intercepts to the extent possible. To calculate this, we use the equation

$$P_p = \frac{(D - A)\theta^2 + (2A - D)\theta}{A}$$

when $A \leq D \leq 2A$. When the defense potential reaches twice the total attack ($D = 2A$), the defense can negate the leak rate almost entirely; i.e., the overall leak rate is reduced to only 1 percent if the basic leak rate is 10 percent. The number of penetrating Soviet RVs decreases in linear fashion between $D = A$ and $D = 2A$.

Relating Percent of Value to Designated Ground Zeros

To translate weapons available to attack value into potential damage to that value, we must first express percent of total value in the currency of designated ground zeros (DGZs). When U.S. and Soviet value is principally composed of theater projection forces, we hold that 4000 DGZs correspond to 90 percent of Soviet value, and that 2400 DGZs correspond to 90 percent of U.S. value. The disparity arises because the Soviet target base associated with theater projection forces is larger and more dispersed than that for the United States.⁴

⁴See Michael M. May, George F. Bing, and John D. Steinbruner, "Strategic Arsenals After START: The Implications of Deep Cuts," *International Security*, Vol. 13, No. 1, Summer 1988, p. 115.

Some analysts will argue that the DGZ curves should be steeper, e.g., that more than 70 percent of the value structure of Soviet projection forces and war-supporting facilities

In Fig. 3, we relate DGZs to percent of value for both the United States and the USSR. Each curve rises steeply at first and then asymptotically (flat), reflecting the concept that DGZs have diminishing value when arranged in rank order.⁵

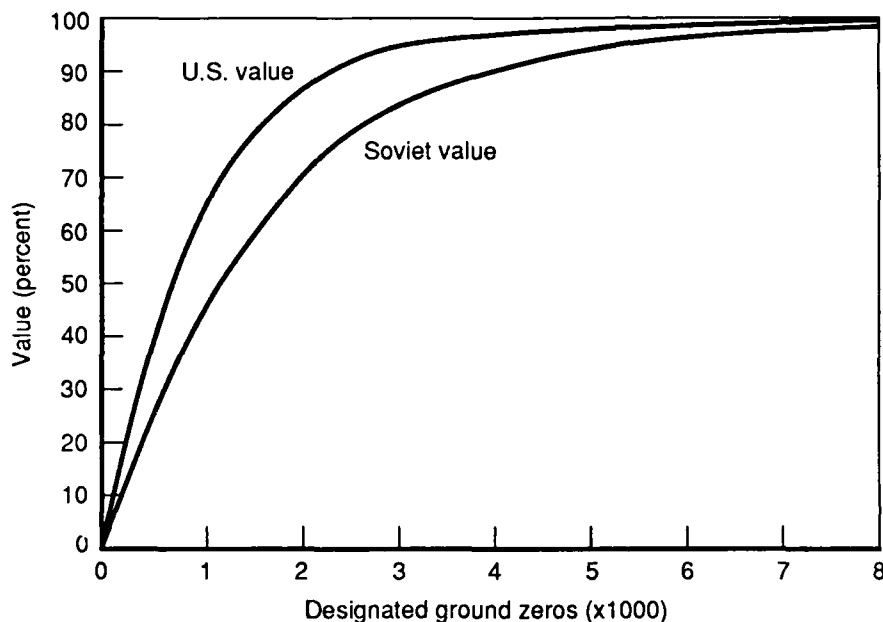


Fig. 3—U.S. and Soviet DGZ curves

is contained in 2000 DGZs (see Fig. 3). This presents a problem, since altering the DGZ curves affects the measure of stability. Steeper curves will cause a greater level of relative first-strike stability (given a specific structure and posture of offensive forces, the level of defense potential, etc.). However, the ranking of two given situations in terms of first-strike stability remains the same.

⁵Many analysts use an approach involving "bar charts." Each bar represents a specific target set, such as "strategic nuclear forces" or "theater projection forces." The bars show how many targets there are in a target set (the top of the bar) and how many targets in that set are destroyed (the part of the bar that is filled). We reject the use of such bar charts as misleading. First, they lack any intellectual basis for determining the tradeoff between limiting damage to oneself and inflicting damage on the adversary. They create the impression that raising the level in the bar representing the target set "strategic nuclear forces" is as important and achieves the same objective as raising the level in the bar representing the target set "theater projection forces." In actuality, holding strategic nuclear forces at risk facilitates limiting damage and erodes first-strike stability, while holding theater projection forces at risk facilitates inflicting damage and

The value associated with a particular DGZ is equivalent to the value destroyed by one weapon arriving at that DGZ. Therefore, 2400 Soviet weapons with a probability of arrival of unity potentially could damage 90 percent of U.S. value. Similarly, 4000 arriving U.S. weapons could destroy 90 percent of Soviet value.

Relating Three Factors: Number of Attacking Weapons, Defense Potential, and Expected Damage to Value

Figure 4 shows the potential damage to U.S. value as a function of U.S. defense potential for the case of a Soviet attack of 5000 RVs and 900 bomber weapons. For the case of "no U.S. defense potential," the Soviets can damage 93 percent of U.S. value structure. If the United States possessed a defense potential of 1000, the Soviet attack has the potential to destroy 88 percent of U.S. value.

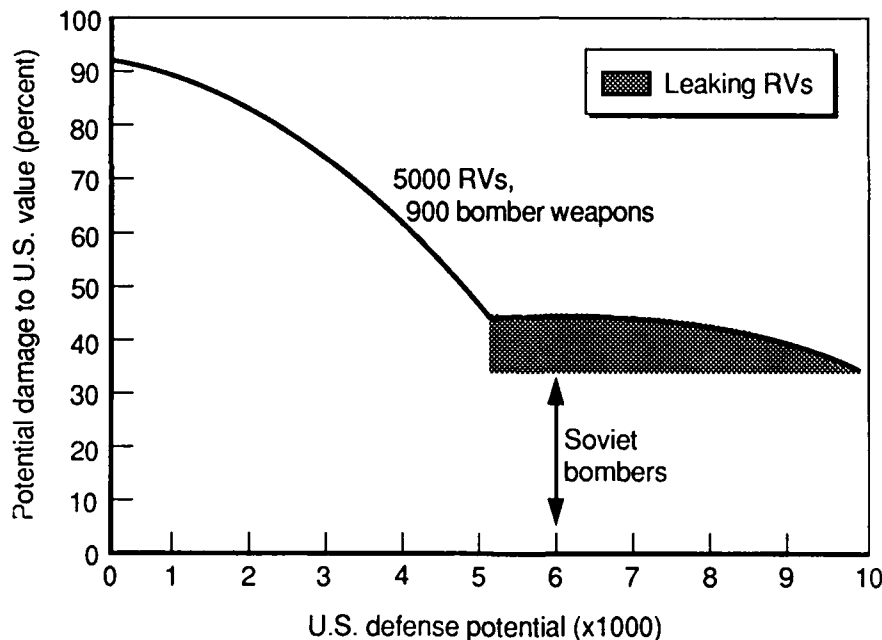


Fig. 4—Relating Soviet weapons attacking U.S. value through U.S. defenses to potential damage to U.S. value

generally enhances first-strike stability. Second, bar charts embody the absurd assumption that all targets within a given target set are of equal value.

The calculations surrounding the latter case will be described in some detail. For 5000 RVs attacking through a defense potential of 1000 with a leak rate of 0.10, the probability of any particular RV penetrating the defenses is 0.82. Coupling this with a reliability of 0.85 gives a probability of 0.70 that any particular RV will arrive and detonate at its assigned target. If one Soviet RV is allocated to each of the first 5000 U.S. DGZs, then 99 percent of U.S. value is at risk. The expected damage is 69 percent of total U.S. value (0.99×0.70).

The Soviets have an alternative attack option. They can allocate two RVs to each of the "first" (most valuable) 2500 U.S. DGZs, which contain 92 percent of the total U.S. value. A two-on-one attack yields a probability of 0.91 that at least one RV will arrive at any particular DGZ of the 2500 being attacked. The expected damage is now 84 percent (0.92×0.91). This, then, represents a better attack option for the case of 5000 Soviet RVs against a U.S. defense potential of 1000.

By examining all relevant attack options, we can finally determine the best option. It turns out in this case that the two-on-one attack of 2500 DGZs is about the best option for the circumstance described.

We must now take into account the additional potential damage to U.S. value from the 900 Soviet bomber weapons. We find that the Soviet bombers would be used most effectively by attacking the "next" 900 DGZs beyond the 2500 DGZs already held at risk by 5000 Soviet RVs. These 900 DGZs contain an additional 5 percent of the total U.S. value. The expected damage from this attack is another 4 percent (0.05 value at risk multiplied by 0.85 reliability and 0.95 penetration, given Soviet defense suppression). Thus, the total expected damage from the Soviet attack is 88 percent (0.84 plus 0.04).

We arrive at the same answer (88 percent) if we mathematically apply the bombers before applying the RVs. Allocating 900 bomber weapons to the first 900 DGZs results in an expected 40 percent damage (0.50 value multiplied by 0.85 reliability and 0.95 penetration with Soviet defense suppression). Allocating 900 RVs to the same 900 DGZs would yield an expected 7 percent damage (0.10 value remaining multiplied by 0.70). Allocating the remaining 4100 RVs two-on-one on the next 2050 DGZs would yield an expected 41 percent of U.S. value damaged (0.45 value multiplied by 0.91). The total expected damage, then, is $0.40 + 0.07 + 0.41$ or 88 percent.⁶

The flatness of the curve in Fig. 4 at the point representing a U.S. defense potential of 1000 indicates that low levels of U.S. defense

⁶We assume that bombers are used preferentially to attack targets situated on the periphery of each country. We discount "value at risk" by 0.85 when attacking with bombers. Thus, whereas 900 DGZs represent 59 percent of U.S. value, 900 Soviet bombers hold at risk only 50 percent (0.59×0.85).

would not deny the Soviets the capability to damage a high percentage of total U.S. value. As U.S. defense potential increases from 1000, however, the curve becomes steeper. The Soviets find it to their advantage to increasingly concentrate their RVs on the higher-value DGZs (those represented by the steep portion of the U.S. DGZ curve in Fig. 3). As a result, the total percentage of U.S. value that the Soviets hold at risk diminishes, and damage to the United States falls ever more rapidly.

A break in the curve in Fig. 4 occurs at the point where the defense potential equals the number of attacking RVs, in this case, 5000. When the defense potential exceeds the number of attacking RVs, damage levels fall less rapidly. Additional defense potential slowly reduces the leak rate, and that beyond the total number of attacking RVs has less effect in terms of limiting damage.

The expected damage from the 900 bomber weapons alone is about 35 percent (0.50 value multiplied by 0.85 reliability and 0.85 penetration—no defense suppression).

The purpose of describing the above calculations in some detail is to give the reader a clear idea of what went into the calculations for subsequent curves that show expected damage to U.S. value as a function of U.S. defense potential for various numbers of attacking RVs.

A Note on the Preferred Defense Mode

In actuality, an attacker probably would orchestrate his attack without knowledge of the mode of his adversary's defense. Likewise, the defender must operate his defenses without necessarily knowing the attacker's allocation of RVs between counterforce and countervalue attacks. Also, if the defender destroyed ballistic missiles in the boost or post-boost phase, he could not determine whether their destinations were silos or targets associated with theater projection forces.

We address the complicating factor of uncertainty in App. B. In particular, we use the concept of "least regrets" to find the preferred mode in which strategic nationwide ballistic missile defenses (and especially boost-phase and post-boost-phase defenses) would probably be operated.

Our analysis in App. B leads us to use the random subtractive mode in the calculations throughout this report. We therefore assume that the defender operates his defenses in a random subtractive mode and that the attacker orchestrates his counterforce and countervalue attacks accordingly. The results of the analysis would not be very different if we had chosen alternative modes for operating defenses.

IV. INCORPORATING STRATEGIC DEFENSES INTO THE METHODOLOGY OF FIRST-STRIKE STABILITY

To examine the degree of first-strike stability inherent in alternative postures of strategic offensive forces in the presence of strategic defenses, we develop the following methodology:

- Draw loci of endpoints for optimal counterforce attacks by one side as a function of the other's defense potential. We do this for a given structure and posture of U.S. and Soviet strategic offensive forces. The resulting curves portray the number of weapons available to each side for attacking of the other's value.
- Draw curves that express the expected damage and expected cost incurred by each nation as a function of the number of weapons available to attack value for various levels of U.S. and Soviet defense potential.
- Calculate values of a stability index to indicate the relative first-strike stability at each combination of U.S. and Soviet defense potential and display the results in a "defense domain."

The relationship between the first and second bullets is a complicated one best likened to the "chicken or the egg" analogy. One cannot determine the loci of endpoints for optimal attacks without knowing the damage and cost associated with these attacks. But one cannot express damage and cost as a function of defense potential without first determining the number of weapons available to each side to attack the adversary's value. We conduct the calculations simultaneously. However, we describe the loci of endpoints first and then the damage and cost associated with the endpoints.

LOCI OF ENDPOINTS FOR OPTIMAL ATTACKS

Given specific structures and postures of strategic offensive forces and the potential of defensive forces, we establish the optimal allocation of offensive forces to counterforce and to countervalue attacks. For example, given a Soviet first strike with current offensive forces

through U.S. defenses of a stated potential (operated in a random subtractive mode), and given that the Soviets believe U.S. offensive forces will be in a stated posture upon the arrival of Soviet RVs, we establish how many RVs the Soviets would allocate to counterforce attack and how many to countervalue attack. We then determine how many U.S. RVs would survive to retaliate against Soviet value.¹

If the side incurring the first strike deploys strategic ballistic missile defenses, the P_p of each attacking RV decreases and its overall probability of kill P_k against an enemy silo diminishes. Therefore, the first-striker may allocate more RVs against each of his adversary's ICBM silos to ensure a high overall P_k in attempting to limit damage to his value. In so doing, the first-striker must be mindful of minimizing his overall cost of the war, and his cost increases when he does not inflict damage on the enemy's value.

Figure 5 shows U.S. and Soviet loci of endpoints for a Soviet first strike as a function of U.S. defense potential. It reflects current U.S. and Soviet offensive force structures, with U.S. offensive forces in posture "B."²

At the far left side of Fig. 5, the United States has no defenses. The Soviets' best first-strike option in this circumstance is to attack U.S. SSBNs in port with 16 RVs and bombers at their bases with 252 RVs, expending a total of 268 RVs. They also attack U.S. silo-based ICBMs with three RVs per silo, expending an additional 3000 RVs. Starting with 9624 on-line RVs, therefore, the Soviets retain 6356 RVs (in addition to 900 bomber weapons) with which to attack U.S. value. Some 3900 U.S. RVs survive and are available to attack Soviet value in retaliation. Over 2600 weapons aboard U.S. bombers on strip alert also survive given tactical warning of the Soviet attack.

As the United States deploys defenses that increasingly interfere with Soviet attacks against its bomber bases, SSBN ports, and silos, the Soviets allocate more RVs to counterforce attacks against these targets to compensate for the reduction in RV penetrability. At a U.S. defense potential of 2500, the Soviets find it to their advantage to allocate 4000 RVs against U.S. silos, 24 RVs against U.S. SSBNs in port, and 378 RVs against U.S. bombers at their bases. The Soviets retain 5218 RVs with which to attack U.S. value and can expect about 3950 U.S. RVs to survive for retaliation.

¹Appendix C demonstrates the process of drawing a set of cross-plots that relate weapons available to attack value to damage inflicted on that value. The cross-plots are used to compare alternative counterforce strategies with a view to selecting the one that minimizes the cost to the first-striker. See also Sec. III above.

²Posture B signifies a medium level of generation of forces for the side incurring the first strike. We assume that the first-striker generates all of his on-line forces and can use them in the attack. See App. A. Details of current U.S. and Soviet strategic offensive force structures also appear in App. A.

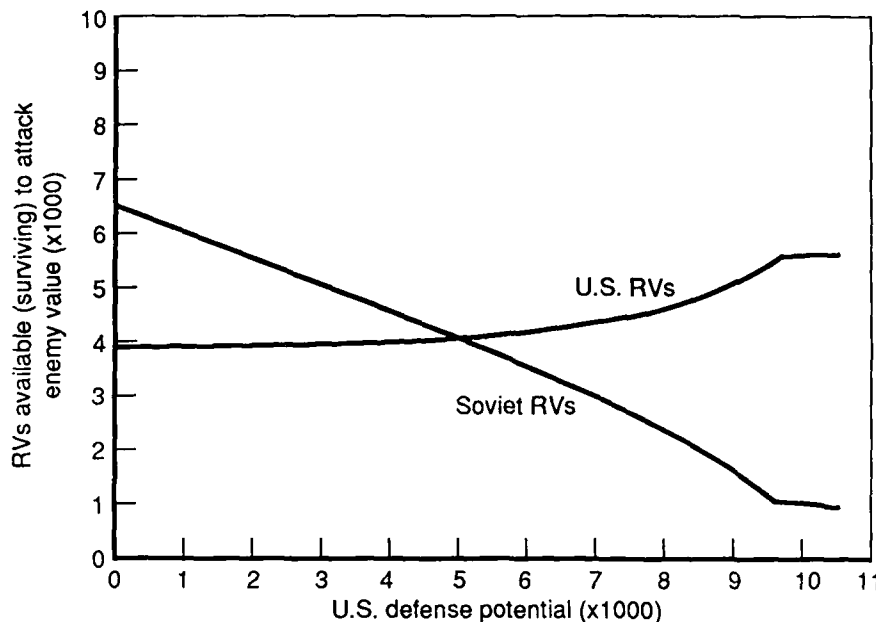


Fig. 5—U.S. and Soviet loci of endpoints as a function of U.S. defense potential—Soviet first strike (current offensive forces, posture B)

When U.S. defense potential reaches 5000, the Soviets adopt a strategy of five RVs on each U.S. silo, exhausting their hard-target-kill capability. Moreover, they increase their expenditure of RVs against U.S. SSBNs in port and bombers on bases to a total of 670. They retain 3954 RVs for use against U.S. value. Despite heavier countersilo attacks, however, the number of surviving U.S. RVs begins to rise (to 4100 at this point) as U.S. defenses cause the overall P_k of each Soviet RV against a U.S. silo to fall significantly. As U.S. defenses are further strengthened, Soviet options are limited to conducting heavier attacks against bomber bases and SSBN ports to maintain high damage expectancy against these targets.

By the time the United States deploys a robust defense potential equaling the total inventory of on-line Soviet RVs, U.S. defenses interfere with the Soviet countersilo attack to the extent that all but 600 U.S. ICBM RVs survive even if the Soviets continue allocating five RVs per U.S. silo. At this point we determine that, to minimize their overall cost, the Soviets change their countersilo strategy to four RVs per U.S. silo in order to allocate 1000 more RVs to attacking U.S. value. They retain some 1000 RVs for countervalue attack, and 5500 U.S. RVs survive for retaliation against Soviet value.

Figure 6 depicts the U.S. and Soviet loci of endpoints (current forces, posture B) as a function of Soviet defense potential when the United States strikes first.³ The same general phenomenon occurs here as appears in Fig. 5: Soviet defenses cause the United States to use more RVs in counterforce. Nevertheless, more Soviet RVs survive to retaliate against U.S. value.

In contrast to the Soviet locus of endpoints in Fig. 5, however, the U.S. locus in Fig. 6 initially slopes downward rather slowly because U.S. countersilo capability is limited. The United States utilizes all of its countersilo capability even when the USSR has no defenses. As the Soviets strengthen their defenses, therefore, U.S. counterforce options are limited to increasing the size of the attack on Soviet bombers at their bases, SSBNs in port, and mobile missiles in garrison. Because of limited U.S. countersilo capability and the many RVs deployed in fixed silos in the USSR, the Soviet locus of surviving RVs in Fig. 6 rises sharply.⁴

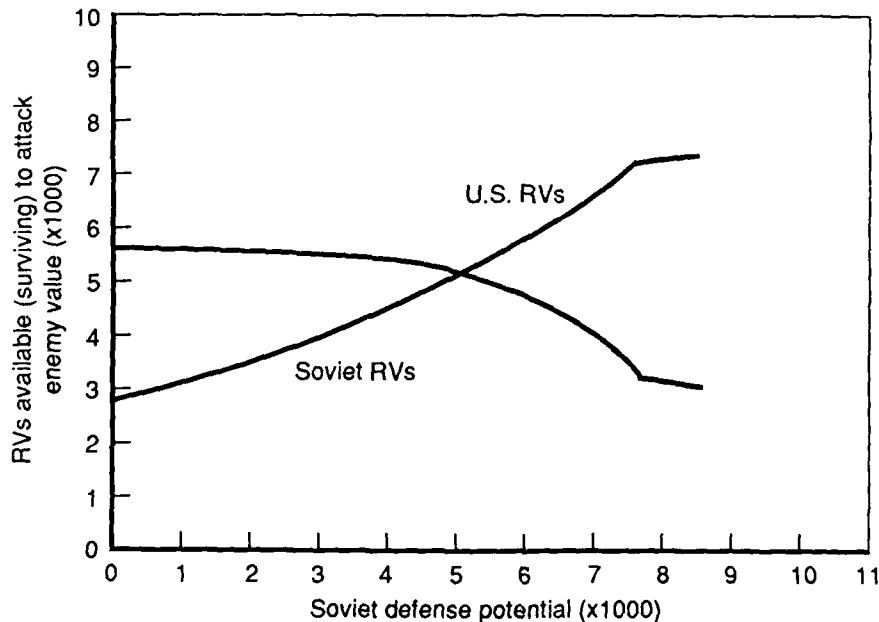


Fig. 6—U.S. and Soviet loci of endpoints as a function of Soviet defense potential—U.S. first strike (current offensive forces, posture B)

³See App. A for a treatment of Soviet forces in posture B.

⁴Some analysts, including many Soviets, often use the term "correlation of forces" to describe the ratio of the initiator's weapons to the victim's weapons available following the counterforce attack. Had the loci of endpoints in Figs. 5 and 6 been drawn on the

RELATING AVAILABLE WEAPONS TO DAMAGE, COST, AND FIRST-STRIKE STABILITY

To this point, we have discussed the characteristics of loci of endpoints that represent interactions of strategic offensive forces in the presence of BMD and express these interactions in terms of weapons available to attack value. We now examine the damage and cost associated with the loci of endpoints. This enables us to indicate in a general sense trends in first-strike stability as the United States and the USSR deploy varying levels of nationwide BMD.

As an example, we examine damage incurred at two combinations of U.S. and Soviet defense potential. Figure 7 compares the damage to U.S. and Soviet value under current conditions (where U.S. and Soviet defense potential is zero) with the damage incurred when both sides deploy intermediate levels of defense. For the latter case, we set U.S. defense potential at 6000 and Soviet defense potential at 4000. Current U.S. and Soviet offensive forces are assumed, with the forces of the side incurring the first strike operating in posture B.⁵

In the case of no defenses, damage to U.S. and Soviet value potentially would be substantial regardless of who struck first; i.e., neither side could limit damage very much in a first strike. In striking first rather than incurring a first strike, the United States could reduce damage to its value by only 12 percent, from 95 to 83 percent. Similarly, the USSR would achieve a mere 7 percent reduction in damage if it struck first rather than incurring a U.S. first strike. Therefore, despite U.S. and Soviet counterforce strategies that minimize to the extent possible the cost to each side of going first, first-strike stability is judged to be robust.

If each country deployed intermediate levels of defense, damage would diminish whether a country struck first or second. However, the level of defenses depicted in Fig. 7, coupled with optimal counterforce

basis of maximizing the correlation of forces rather than minimizing the cost, they would exhibit the same phenomena of decreasing numbers of available RVs for the initiator and increasing numbers of surviving RVs for the defender as the defenses became more robust. Thus, the correlation of forces would favor the initiator at low levels of defense but would be reversed at robust levels.

Some may be inclined to stop here, claiming that U.S. strategic nationwide BMD provides leverage against the USSR by reversing the correlation of forces in favor of the United States if the Soviets strike first (Fig. 5). However, as demonstrated in Fig. 6, Soviet defenses also reverse the correlation of forces in favor of the USSR if the United States strikes first.

Moreover, using the correlation of forces as a measure of merit is incomplete because it does not address the effect of defenses in a U.S. or Soviet first strike on: (1) the potential damage that available Soviet RVs and bomber weapons could inflict on U.S. value or (2) the potential damage that available U.S. weapons could inflict on Soviet value.

⁵See App. A.

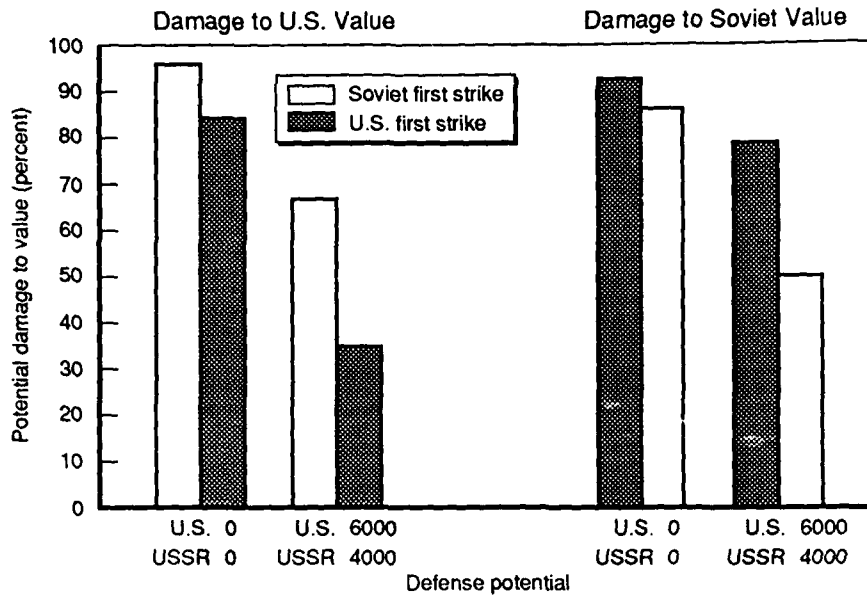


Fig. 7—Effect of intermediate defenses on damage to U.S. and Soviet value (current offensive forces, posture B)

strategies, would allow each side to limit damage considerably in striking first rather than waiting and incurring a first strike. The United States could reduce damage to its value from 66 to 34 percent in striking first, while the USSR could limit its damage from 78 to 49 percent in striking first. In light of this initial assessment, we could conclude that first-strike stability would not be as great at intermediate levels of defense as when defenses are absent.

Curves Depicting Damage to Value as a Function of Defense Potential

To track trends in damage levels more rigorously as the superpowers deploy defenses, we now show curves of the percent of value damaged at varying levels of defense potential. These curves depict the damage levels associated with the optimal counterforce strategies expressed through the loci of endpoints in Figs. 5 and 6 above.

Figure 8 demonstrates potential damage to U.S. value as a function of U.S. defense potential, given various levels of Soviet defense potential. The dashed curve represents damage to U.S. value from a Soviet first strike. We portray only one dashed curve because damage to U.S. value does not depend on Soviet defense potential when the Soviets strike first.⁶ The gap between the dashed curve and the solid curves relates to the amount of instability in a given situation.

If the United States struck first, Soviet defenses then would affect the damage to U.S. value by inhibiting the U.S. ability to limit damage through counterforce attacks. We therefore depict damage to U.S. value from Soviet retaliation by a family of solid curves, each representing a different level of Soviet defense potential.

The breaks in the solid curves in Fig. 8 occur when the overwhelm point of U.S. defenses (i.e., their defense potential) equals the number of surviving Soviet RVs. The locus of endpoints for Soviet RVs in Fig.

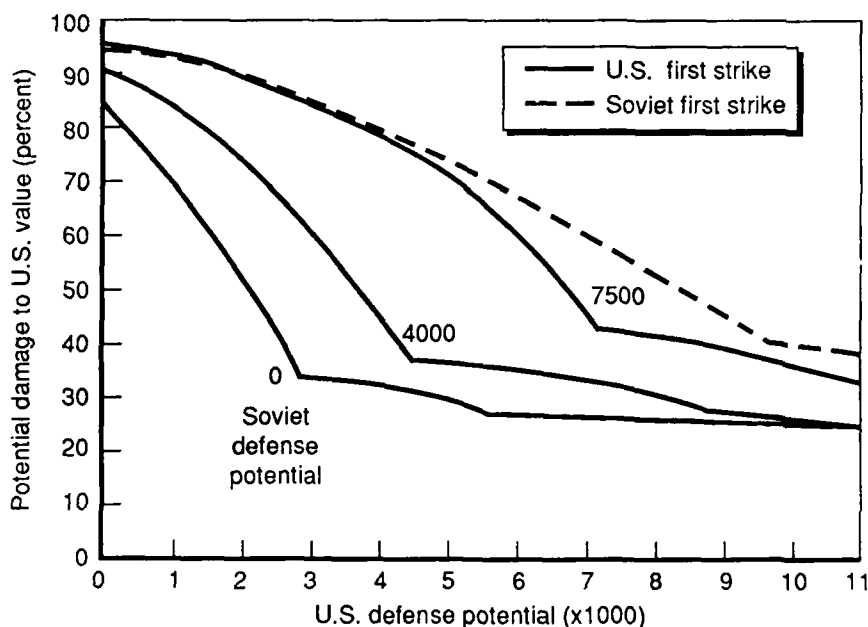


Fig. 8—Potential damage to U.S. value as a function of U.S. defense potential (current offensive forces, posture B)

⁶See Sec. III and App. C for a discussion on the derivation of curves that relate value damaged to defense potential.

6 above shows that, in the absence of Soviet defenses, 2800 Soviet RVs survive a U.S. counterforce attack. The first break in the solid curve in Fig. 8 labeled "0 Soviet defense potential" thus occurs at a U.S. defense potential of 2800. The second break on that same curve appears when U.S. defenses conduct two-on-one interceptions of each RV at a U.S. defense potential of 5600.

An interesting phenomenon in Fig. 8 occurs at a Soviet defense potential of 7750 between U.S. defense potentials of 0 and 1000. A small region appears where damage to U.S. value is about the same whether the United States strikes first or second. At some points, in fact, U.S. damage may be *greater* in a U.S. first strike than in a second because the U.S. counterforce first strike is virtually nullified by Soviet defenses, bringing the full weight of Soviet capability to bear against U.S. value in retaliation. In a Soviet first strike, however, the Soviets attempt to limit damage to themselves by allocating many weapons against U.S. strategic retaliatory forces rather than against U.S. value. This phenomenon does not extend to cost because cost also involves damage not inflicted on enemy value, and Fig. 10 (below) will reveal that the U.S. cost of striking first is somewhat less than its cost of striking second.

Figure 8 demonstrates that the difference in damage to U.S. value between going first and incurring a first strike is greatest at intermediate levels of U.S. defense potential (between about 3000 and 7000). Intuitively, we can foresee an increase in first-strike instability at these levels.

Figure 9 relates Soviet value damaged to Soviet defense potential, given various levels of U.S. defense potential. As would be expected, Soviet defenses reduce the percentage of Soviet value damaged as a consequence of a strategic nuclear exchange. As they deploy defenses, the Soviets, like the United States, benefit from a greater ability to limit damage in a first strike than in a second. Again, the greatest differences in Soviet damage between initiating and striking second occur in the middle of Fig. 9, where Soviet defense potential is at intermediate levels.

Curves Depicting Cost as a Function of Defense Potential

The next step toward representing the relative stability of the posture of offensive forces in the presence of defenses is to translate the curves that depict value damaged as a function of defense potential into curves that depict cost as a function of defense potential. We use the cost function presented in Sec. II. The cost curves will show the extent to which each side's counterforce strategies minimize cost in the presence of BMD.

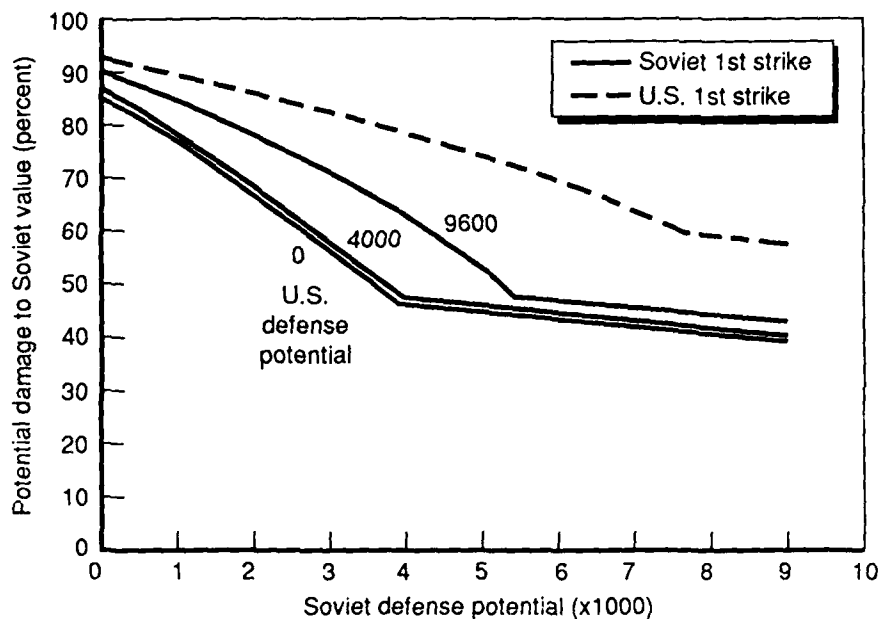


Fig. 9—Potential damage to Soviet value as a function of Soviet defense potential (current offensive forces, posture B)

Figure 10 depicts the cost to the United States of striking first and second (C_1^{US} and C_2^{US} respectively) as a function of U.S. defense potential and for various levels of Soviet defense potential. The shapes of the curves in Fig. 10 resemble those of the curves in Fig. 8. In contrast to Fig. 8, however, Fig. 10 contains a family of dashed curves representing the U.S. cost associated with a Soviet first strike. Soviet defense potential influences the U.S. cost of going second because cost incorporates a second term involving damage not inflicted on enemy value, and Soviet defenses inhibit U.S. ability to inflict damage on Soviet value.

As with damage, the U.S. cost of a nuclear war diminishes as U.S. defense potential rises whether the United States strikes first or second. However, U.S. cost is reduced faster if the United States strikes first. The difference between the U.S. cost of striking first and its cost of striking second is greatest at intermediate levels of U.S. defense potential.

Figure 11 depicts the costs to the Soviets of striking first and second as a function of Soviet defense potential and for various levels of U.S.

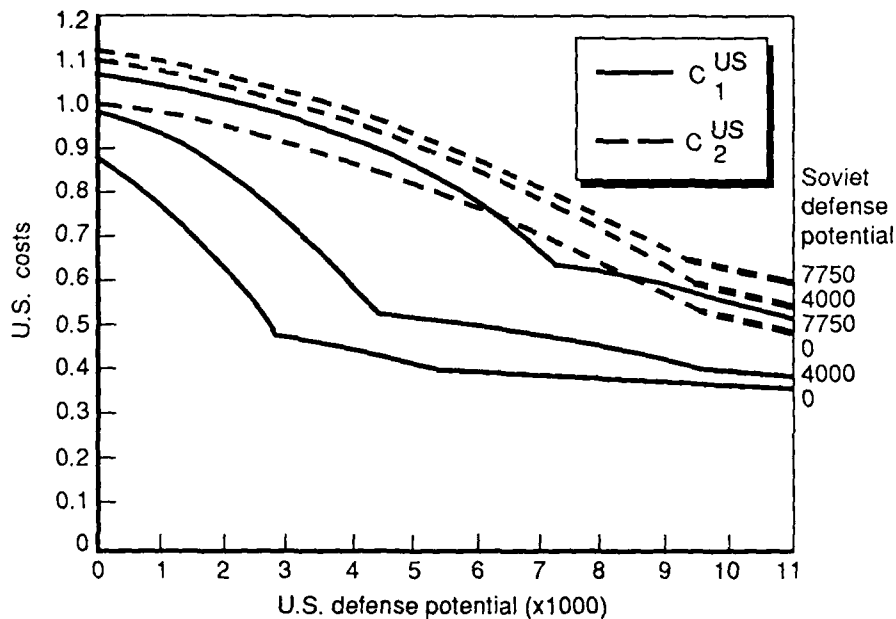


Fig. 10—U.S. costs as a function of U.S. defense potential
(current offensive forces, posture B)

defense potential. As in Fig. 10, the area of greatest difference between the Soviet costs of striking first and second appears at intermediate Soviet defense potentials.

CONVERTING COSTS INTO AN INDEX AND PLOTTING VALUES OF THE INDEX IN A DEFENSE DOMAIN

The Index of First-Strike Stability

The interaction of a stated structure and posture of U.S. and Soviet offensive forces in the presence of a given combination of U.S. and Soviet defense potentials yields four costs: C_1^{US} , C_2^{US} , C_1^{Sov} , and C_2^{Sov} . We combine these costs into a numerical index of first-strike stability.⁷ The index combines the four costs as follows:

⁷For a derivation, see Part I, pp. 24-29. The index of first-strike stability is *not* a vehicle for predicting the likelihood of war given a deepening crisis (crisis stability). We use the index only as an indicator of which postures of strategic forces are more likely to act as mitigators or catalysts to instability in a crisis.

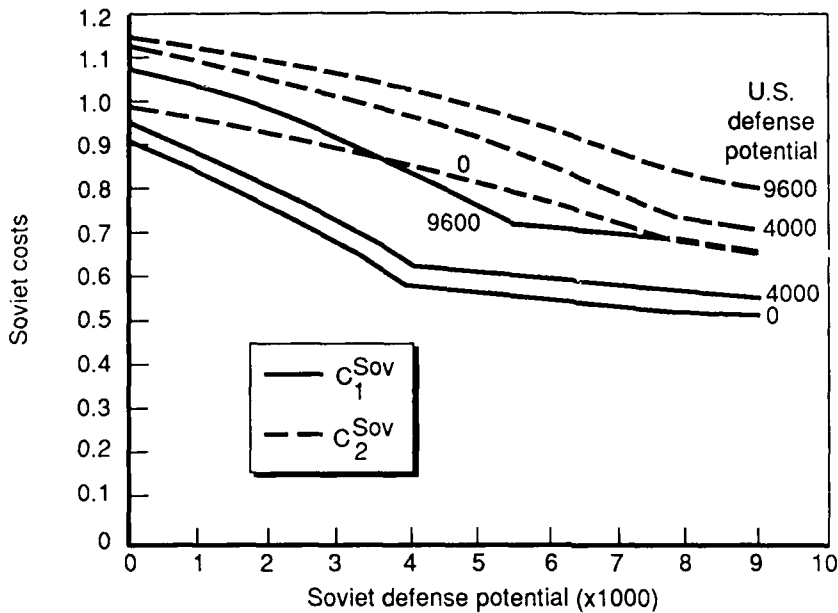


Fig. 11—Soviet costs as a function of Soviet defense potential (current offensive forces, posture B)

$$\text{Stability index} = \left(\frac{C_1^{\text{US}}}{C_2^{\text{US}}} \right) \left(\frac{C_1^{\text{Sov}}}{C_2^{\text{Sov}}} \right).$$

The index ranges from 0 to 1.0, with 0 denoting the lowest level of first-strike stability and 1.0 the highest level.

Using this formula, we can calculate the index of first-strike stability for the two cases displayed in Fig. 7. In the case of no defenses (current offensive forces, posture B), reading the curves in Figs. 10 and 11 gives $C_1^{\text{US}} = 0.89$, $C_2^{\text{US}} = 1.0$, $C_1^{\text{Sov}} = 0.90$, and $C_2^{\text{Sov}} = 0.98$, yielding a stability index of 0.82. This index is high, approaching 1.0.

When the superpowers deploy intermediate defenses (6000 U.S. defense potential and 4000 Soviet defense potential), the costs diminish to $C_1^{\text{US}} = 0.50$, $C_2^{\text{US}} = 0.86$, $C_1^{\text{Sov}} = 0.67$, and $C_2^{\text{Sov}} = 1.0$, yielding an index of 0.39. The case of intermediate defenses, therefore, exhibits less first-strike stability than the case of no defenses.

The Defense Domain

To provide an overall view of how the presence of strategic defenses affects first-strike stability, we plot values of the index in a "defense domain." The defense domain depicts all combinations of U.S. and Soviet defense potential for a given structure and posture of strategic offensive forces.⁸

Figure 12 provides an example of a defense domain where each side maintains 5000 on-line ballistic missile RVs in its inventory. The lower left corner of the domain represents an offense-dominant environment—e.g., the current world characterized by large offensive forces and strategic defenses that are severely constrained.

In the upper right corner of the domain, the overwhelm point of each side's defenses equals the total number of usable (on-line) RVs in the adversary's inventory. Thus, defenses can even absorb a first strike, allowing only a few RVs to penetrate because of the leak rate

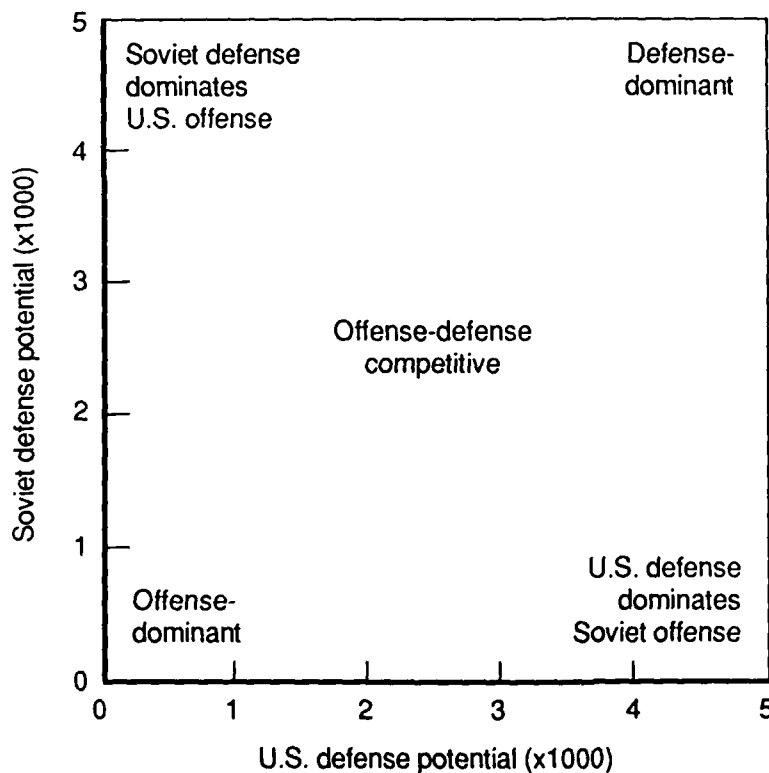


Fig. 12—Generic defense domain

⁸See also Kent and DeValk, 1986.

inherent in the system. This environment may be considered defense-dominant, at least concerning ballistic missiles.⁹

The upper left and lower right corners of the defense domain depict situations in which one side deploys a robust defense whose overwhelm point equals the total number of on-line RVs in the adversary's inventory, while the adversary forgoes any deployment of his own. The middle of the domain represents cases where the offense and the defense compete for supremacy.¹⁰

We calculate the stability index for each combination of U.S. and Soviet defense potential and plot these values at the appropriate intersections on the defense domain. Then we draw isolines of constant values of the index throughout the defense domain. The resulting picture resembles a weather or topographical map.

APPLYING THE METHODOLOGY

Current U.S. and Soviet Strategic Offensive Forces

Figure 13 provides isolines of constant values of the index in the defense domain for current U.S. and Soviet strategic offensive forces operating in posture B.

The lower left corner of the domain depicts the current offense-dominant environment and exhibits fairly robust first-strike stability. Each side maintains large, survivable retaliatory forces. The ability of surviving RVs to reach their targets is constrained only by the reliability of the delivery vehicles upon which they are carried.

In the upper right corner, the stability index also is high. Even if a leader struck first with all the RVs he could muster, he could expect only a small fraction to penetrate the adversary's defenses. In a defense-dominant environment for ballistic missiles, bombers become the dominant force, and the alert rate of bombers drives the stability index. If each side has substantial bomber forces and these bombers

⁹The defense domain can be extended beyond the total number of usable RVs. For instance, the upper right corner of the domain could represent U.S. and Soviet defense potentials of 10,000, cutting the leak rate from 10 percent to 1 percent because two interceptors or shots can be allocated to each attacking RV. We limit ourselves, however, to the more interesting, dynamic areas of the defense domain.

¹⁰In reality, if either or both sides chose to deploy defenses in competition, each side would also increase its offensive forces in reaction to the opponent's defense deployments. In a competitive environment, probably neither unilateral defense dominance (the lower right and upper left corners of the defense domain) nor mutual defense dominance (the upper right corner) with regard to ballistic missiles would be achievable. Competition would begin to enforce situations equivalent to those represented by the middle of the domain.

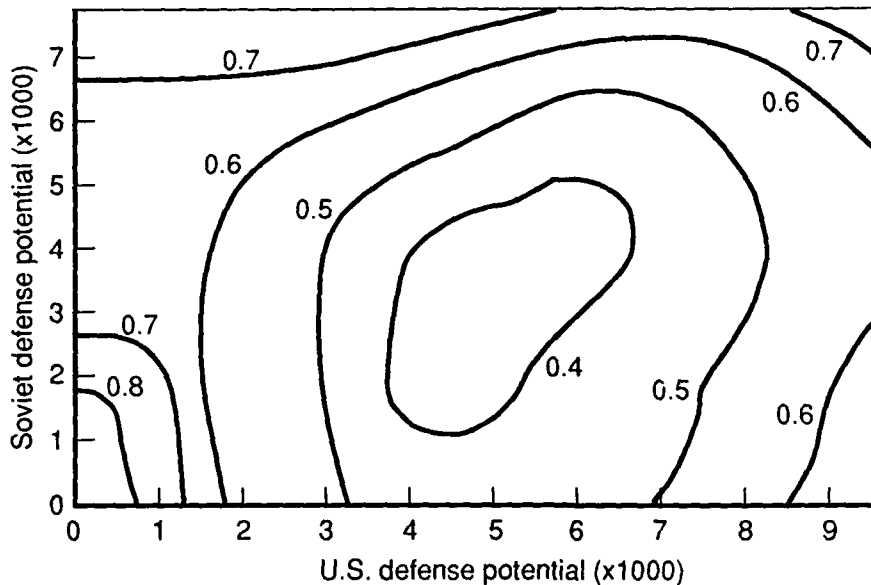


Fig. 13—Isolines of constant values of the stability index in the defense domain (current offensive forces, posture B)

are maintained at posture B alert rates, the stability index will remain high. Neither side can limit damage greatly by striking first.

In the opposing corners where there is a unilateral deployment of high levels of defense, we again find fairly high values of the index. Neither side fares much better by striking first rather than waiting and incurring a first strike. The country that has ballistic missile defenses succeeds in preventing the penetration of all but a small fraction of the adversary's RVs even if the other country strikes first. Any damage that country suffers is due to bomber weapons on alert, regardless of who strikes first. Conversely, the undefended country suffers devastation from both RVs and bomber weapons, regardless of who strikes first.

Toward the middle of Fig. 13, the values of the stability index diminish, and a "sinkhole" of relative first-strike instability exists in the center of the domain. To understand the basis for this sinkhole, we return to the curves in Figs. 8 and 9, above, relating value damaged to defense potential. At the levels of defense potential represented by

the middle of the defense domain, each side could substantially limit damage by striking first, hence first-strike stability is eroded.¹¹

The sinkhole tends to be deeper close to the axis representing U.S. defense potential. This derives from the small size and low alert rate of the Soviet bomber force, which is inadequate to fill the void created by the low penetrability of Soviet RVs in a Soviet retaliatory strike. The United States, therefore, can limit damage to a considerable extent in a first strike. The reverse is not the case near the Soviet axis. Although penetrability of U.S. RVs in a second strike is low, the U.S. bomber force is large enough and effective enough to fill more of the void, and the Soviets cannot limit damage substantially in a first strike.¹² Thus, the values of the index are higher in this area than in the area near the U.S. axis. However, these values are nowhere as high as in the lower left corner.

Modernized U.S. and Soviet Strategic Offensive Forces Constrained by START

Figure 14 shows the stability index for an alternative structure of forces: strategic offensive forces modernized within the constraints of START. The assumed posture is unchanged from posture B.¹³ Figure 14 demonstrates that moving in any direction away from the lower left corner erodes first-strike stability.

Based on the bomber forces we have assumed under START, changes in the values of the index are not as pronounced in the domain depicting modernized, START-constrained offensive forces as they are in the domain portraying current offensive forces. Both U.S. and Soviet bomber forces are large and effective and can substantially damage the adversary's value in a first or second strike.¹⁴

We have assumed that a modernized Soviet bomber force will have capabilities similar to those of the U.S. bomber force against the adversary's value. Thus, we find the lowest values of the stability index toward the center of the domain in Fig. 14 rather than toward the U.S. axis.

¹¹RAND colleagues Dean Wilkening and Kenneth Watman have demonstrated similar areas of instability using a completely different methodology. See Dean Wilkening and Kenneth Watman, *Strategic Defenses and First-Strike Stability*, The RAND Corporation, R-3412-FF/RC, November 1986; and Dean Wilkening, Kenneth Watman, Michael Kennedy, and Richard Darilek, *Strategic Defenses and Crisis Stability*, The RAND Corporation, N-2511-AF, April 1989.

¹²See App. D.

¹³See App. A.

¹⁴See App. D.

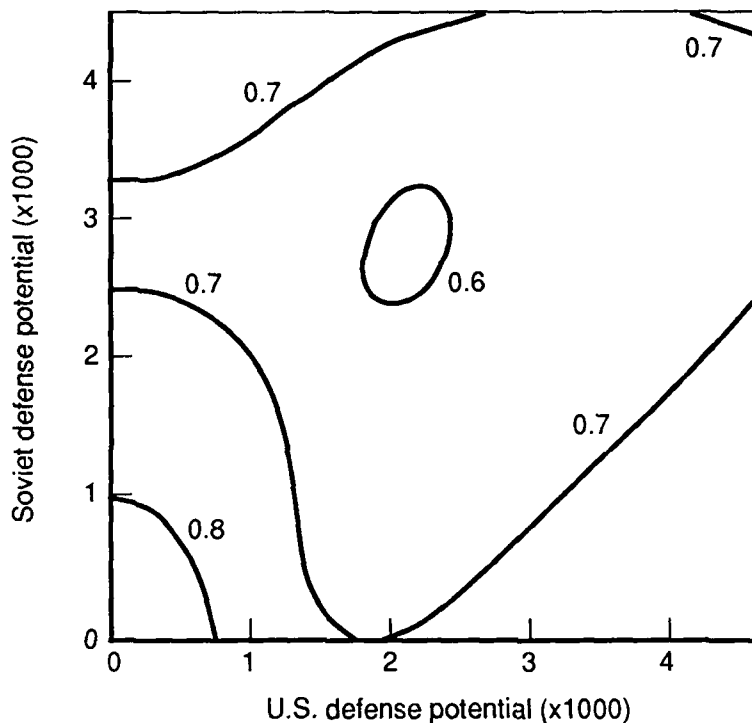


Fig. 14—Isolines of constant values of the stability index in the defense domain (modernized, START-constrained offensive forces, posture B)

The Effect of Alternative Postures of Offensive Forces

So far, we have assumed that the first-striker believes that his adversary could generate his offensive forces to posture B (a medium state of generation) by the time the first strike arrives. Altering the posture of offensive forces demonstrates how the posture drives the index of first-strike stability.

Table 1 displays the stability index at two points in the defense domain—at U.S./Soviet defense potentials of 0/0 and 6000/4000—for current U.S. and Soviet strategic offensive forces in postures A, B, and C.¹⁵ Table 1 shows that under current conditions (BMD is absent), damage levels incurred by each country, and hence the costs to each, are high regardless of who strikes first. Even in posture A, denoting a

¹⁵See App. A. Posture A represents a peacetime state of generation, posture B a medium state, and posture C the maximum state.

Table 1

EFFECT OF THE POSTURE OF CURRENT STRATEGIC
OFFENSIVE FORCES ON FIRST-STRIKE
STABILITY IN THE PRESENCE OF BMD

U.S./Soviet Defense Potential	Posture	Damage (percent)				Cost				Index
		D ₁ ^{US}	D ₂ ^{US}	D ₁ ^{Sov}	D ₂ ^{Sov}	C ₁ ^{US}	C ₂ ^{US}	C ₁ ^{Sov}	C ₂ ^{Sov}	
0/0	A	72	95	80	92	0.80	1.01	0.86	1.0	0.68
	B	83	95	85	92	0.89	1.0	0.90	0.98	0.82
	C	91	95	92	92	0.95	0.98	0.95	0.96	0.96
6000/4000	A	7	66	37	78	0.21	0.89	0.55	1.09	0.12
	B	34	66	49	78	0.50	0.86	0.67	1.0	0.39
	C	50	66	69	78	0.65	0.81	0.84	0.95	0.70

peacetime posture of forces, U.S. and Soviet offensive forces exhibit a stability index of 0.68. Thus, it can be concluded that the lower left corner of the defense domain poses few problems with regard to first-strike stability.

When the United States and USSR deploy strategic nationwide BMD potentials of 6000 and 4000, respectively, damage levels can vary drastically depending on who strikes first. This applies especially when strategic offensive forces operate in posture A. The United States avoids damage almost completely in first strike because (1) the U.S. counterforce attack draws down Soviet RVs below the overwhelm point of U.S. defenses, and (2) no Soviet bombers are assumed on alert in posture A and are destroyed on the ground in the U.S. attack. With Soviet forces in posture A, the United States incurs only 7 percent damage from retaliating Soviet RVs leaking through U.S. defenses, rather than the 66 percent damage that would come from a Soviet first strike.

In striking first, the Soviets also can substantially limit damage to their value assuming that U.S. offensive forces are perceived to operate in posture A. Combining the U.S. and Soviet capabilities to limit damage in a first strike yields a stability index of 0.12, indicative of acute first-strike instability.

Table 1 demonstrates that reducing the vulnerability of each side's strategic offensive forces (operating in more survivable postures) raises the index substantially. However, even with maximum generation of strategic offensive forces (posture C), the stability index diminishes

from 0.96 when defenses are absent to 0.70 when each side deploys intermediate defenses.

Insights from Applying the Methodology

Figures 13 and 14 demonstrate that moving from the lower left corner in any direction—whether the United States or USSR deployed defenses unilaterally, or both deployed in competition with the other—necessarily reduces the index of first-strike stability. Table 1 shows that first-strike stability is reduced regardless of the posture of forces, and that some postures in the presence of intermediate defenses can lead to acute first-strike instability. We argue, therefore, that *the avowed reason for deploying strategic nationwide ballistic missile defenses cannot be to enhance first-strike stability.*

This is a narrow argument: We do not contend that transitioning from a fairly stable offense-dominant environment to a fairly stable defense-dominant environment is impossible. We merely say that first-strike stability is not enhanced by deploying intermediate (or partial) nationwide BMD and cannot logically be the reason for deploying such defenses.

At the same time, the results depicted in the defense domains suggest that a “window” may exist in which U.S. and Soviet strategic nationwide BMD could be robust in defending against limited attacks such as third-country ballistic missile attacks, unauthorized attacks, and accidental launches, yet not so robust that first-strike stability is seriously threatened.

The isolines in the lower left corners of the defense domains in Figs. 13 and 14 indicate that the index remains high as low levels of U.S. and Soviet defense are deployed. Under current offensive forces (Fig. 13), the stability index without strategic defenses is 0.82; this diminishes to 0.73 at defense potentials of 1000 on each side but falls more precipitously at higher defense potentials. Similarly, given modernized, START-constrained forces (Fig. 14), the stability index is reduced from 0.84 in the case of no defenses to 0.74 at defense potentials of 1000. According to both figures, therefore, defenses with potentials not exceeding 1000 might not seriously erode first-strike stability.

The question of whether the United States (and USSR) should deploy low levels of BMD against limited attacks should be debated and its implications should be analyzed. The issues raised should include how the ABM Treaty might be modified, how such defenses could affect U.S. relations with its allies that maintain smaller nuclear forces, and what measures might be taken to keep the “window” open to ensure that first-strike stability is not very affected. We have conducted a preliminary analysis suggesting that certain architectures of

strategic defenses would play a role in keeping this "window" open as wide as possible. Most important, the superpowers would need to maintain highly survivable postures of offensive forces.

V. CONCLUDING REMARKS

This report provides a transparent methodology for analysts to explore the relationship between strategic nationwide ballistic missile defenses and first-strike stability. We believe that use of the methodology will foster a greater understanding of how to evaluate proposals to modernize offensive forces, to deploy strategic defenses, and to reduce and constrain offensive weapons.

Applying the methodology leads to the following conclusions:

- First-strike stability under current conditions is quite robust.

We have demonstrated through this methodology that because neither the United States nor the USSR currently can greatly limit damage in a first strike, neither side can substantially reduce the cost of a nuclear war by striking first. Thus, neither leader is likely to be perceived as pressured by the posture of forces to launch first in a deepening crisis to avoid the worse consequence of going second, and hence first-strike stability remains robust. This is true even if the would-be first-striker believed that his attack could catch his adversary's forces at low alert rates—i.e., in posture A.

- Competitive deployment of strategic nationwide ballistic missile defenses by the superpowers could erode first-strike stability.

An unconstrained competition in deploying strategic defenses could lead to situations where either leader (or both) believed that the adversary's strategic defenses could protect against a retaliatory second strike. In such an environment, each leader could believe that both nations would be able to limit damage in a first strike but not in a second. This would promote a perception on each side of a widening gap between each side's costs of striking first and striking second, thereby eroding first-strike stability.

- Enhancing first-strike stability cannot be the avowed reason for deploying strategic nationwide ballistic missile defenses.

This follows logically from the preceding observations. Deploying intermediate levels of nationwide defense erodes, not enhances, first-strike stability. And there is no pressing problem in the first place. First-strike stability currently is robust and will remain so under the emerging START treaty.

- Neither country would be likely to continue to adhere to agreements that constrain and reduce offensive arms under the specter of intent by the other to deploy strategic defenses outside the constraints of a treaty limiting strategic defenses.

Increasing strategic offensive forces would be one obvious and likely response to an adversary's deployments of strategic defenses. Such a response would be designed to maintain a robust retaliatory capability against the adversary's value through his defenses. Neither the United States nor the USSR should therefore agree to reduce and constrain offensive forces in the presence of intent by the other to unilaterally deploy strategic defenses in contravention to a treaty limiting strategic defenses to low levels—i.e., defenses adequate to protect against third-country attack or unauthorized Soviet attacks.

The expression of intent by either side to deploy defenses beyond low levels would necessarily compound efforts to conclude START. Even if concerns over adherence to the ABM Treaty were set aside and START were completed, each side would surely reserve the right to expand its offensive forces in response to clear intent by the other to deploy intermediate or robust defenses.

- There may be a "window" in which U.S. and Soviet strategic nationwide BMD could effectively defend against such "limited" attacks as third-country ballistic missile attacks, unauthorized attacks, and accidental launches, yet not so robust that first-strike stability is seriously undermined.

Low levels of U.S. and Soviet strategic defense (for example, defense potentials of 500 to 1000) could guard against some of these limited attacks without greatly affecting first-strike stability, even after reductions of offensive arms under START. But first-strike stability in such circumstances could be maintained *only through U.S.-Soviet agreement on permitted defense deployments*—careful modification of the ABM Treaty.

- The level of U.S. defenses attributed to the so-called "Phase I" deployment seems to go beyond the upper bounds of this "window."

Pronouncements in the public domain indicate that the "Phase I" deployment of U.S. strategic nationwide BMD should be capable of intercepting well over 1000 RVs.¹ According to the analysis in this

¹See speech by Secretary of Defense Dick Cheney at the National Press Club, Washington, D.C., March 22, 1990.

study, such levels of defenses could begin to seriously erode first-strike stability.

- Maintaining effective bomber forces on both sides would be critical to any attempt to transition from an offense-dominant world to a defense-dominant world with respect to ballistic missiles.

Substantial and capable bomber forces on the two sides would prevent first-strike instability from becoming acute at levels of ballistic missile defense where a first strike could overwhelm the other side's defenses, but a ragged retaliatory attack with ballistic missiles could not. Even if none of the retaliator's RVs penetrate the first-striker's defenses, neither side could avoid considerable damage when striking first if both had bomber forces capable of inflicting high levels of damage on the first-striker. In such a context, in an absolute sense, the costs to each side of striking first and second would remain significant.

This suggests that any future transition to a situation in which each side's BMD dominates the opponent's ballistic missiles must include a careful negotiation on the critical role of bomber forces in maintaining first-strike stability. Ensuring that such forces remain survivable and effective would probably involve strict limitations on air defenses and possibly on deployment areas of ballistic missile and cruise missile submarines.

Appendix A

U.S. AND SOVIET STRATEGIC OFFENSIVE FORCE STRUCTURES AND POSTURES

U.S. AND SOVIET STRATEGIC OFFENSIVE FORCE STRUCTURES

Throughout this study, we refer to force structures and the force postures within those force structures. Force *structure* is (1) the systems that constitute the force (missiles, bombers, submarines); (2) the capabilities of those systems (probability of kill, reliability, probability of penetrating, hardening against nuclear effects); and (3) the basing mode (mobility, redundancy).

The U.S. and Soviet strategic offensive force structures presented in Tables A.1 and A.2 are based on figures in *Modernizing U.S. Strategic Offensive Forces: Costs, Effects, and Alternatives*, Congressional Budget Office, November 1987; "Strategic Nuclear Forces of the United States and the Soviet Union," ACA Fact Sheet, June 1989; and Edward L. Warner III and David A. Ochmanek, *Next Moves: An Arms Control Agenda for the 1990s*, Council on Foreign Relations, New York, 1988. The postulated U.S. and Soviet force structures in Tables A.3 and A.4 are used only for the purpose of illustration.

U.S. AND SOVIET STRATEGIC OFFENSIVE FORCE POSTURES

Force *posture* defines the proportion of forces that cannot be targeted effectively. Bombers on strip alert, SSBNs at sea, and mobile ICBMs when dispersed are considered nontargetable because of the location uncertainty that we have postulated for them. That is, we assume that the attacker would consider attacks on these elements counterproductive.

Although silo-based ICBMs maintain a constant alert rate that approaches 100 percent, they are targetable. They become nontargetable if the attacker believes that his opponent will launch them under attack (based on tactical warning).

In this study, each force structure may be operated in three basic force postures: A, B, and C. The posture applies specifically to the forces of the side incurring the first strike; we assume that the first-striker generates his forces to posture C, at least before the retaliatory attack arrives. Table A.5 shows a breakdown of postures postulated for our force-exchange calculations.

Table A.1

CURRENT U.S. STRATEGIC OFFENSIVE FORCE STRUCTURE

Force	Number	RVs per Missile	Total RVs	RVs On Line
ICBMs				
Minuteman II	450	1	450	450
Minuteman III	500	3	1500	1500
MX/Peacekeeper (silo)	50	10	500	500
Total	1000		2450	2450
SLBMs				
C-3	240	10	2400	2240
C-4	384	8	3072	3072
Total	624		5472	5312
Total ballistic missiles	1624		7922	7762
		Weapons per Bomber	Total Weapons	Weapons On Line
Bombers				
B-52G/ALCM	98	16	1568	1408
B-52H/ALCM	78	20	1560	1400
B52H	18	8	144	128
B1B/ALCM	2	8	16	16
B-1B	95	16	1520	1376
Total	291		4808	4328
Total missiles and bombers	1915		12730	12090

Table A.2

CURRENT SOVIET STRATEGIC OFFENSIVE FORCE STRUCTURE

Force	Number	RVs per Missile	Total RVs	RVs On Line
ICBMs				
SS-11	376	1	376	376
SS-13	60	1	60	60
SS-17	108	4	432	432
SS-18	308	10+	3080	3080
SS-19	330	6	1980	1980
SS-24 (silo)	30	10	300	300
SS-24 (rail)	20	10	200	200
SS-25 (road)	144	1	144	144
Total	1376		6572	6572
SLBMs				
SS-N-6	240	1	240	208
SS-N-8	286	1	292	256
SS-N-17	12	1	12	12
SS-N-18	224	7	1568	1456
SS-N-20	100	9	900	800
SS-N-23	80	4	320	320
Total	942		3332	3052
Total ballistic missiles	2318		9904	9624
		Weapons per Bomber	Total Weapons	Weapons On Line
Bombers				
Bear H/ALCM	75	6	450	408
Bear A	15	2	30	26
Bear B/C/G	70	4	280	252
Blackjack	10	24	240	216
Total	170		1000	902
Total missiles and bombers	2488		10904	10526

Table A.3

**MODERNIZED U.S. STRATEGIC OFFENSIVE FORCE STRUCTURE
CONSTRAINED BY START**

Force	Number	RVs per Missile	Total RVs	RVs On Line	
ICBMs					
Minuteman III	85	3	255	255	
Minuteman IV (silo)	681	1	681	681	
MX (rail)	50	10	500	500	
Total	816		1436	1436	
SLBMs					
D-5	408	8	3264	3072	
Total ballistic missiles	1224		4700	4508	
		Weapons per Bomber Counted/Actual	Total Counted Weapons	Total Actual Weapons	Actual Weapons On Line
Bombers					
B-52/ALCM	84	12/12	1008	1008	912
B-52	60	1/8	60	480	432
B-1B	100	1/16	100	1600	1440
ATB/B-2	132	1/12	132	1584	1428
Total	376		1300	4672	4212
Total missiles and bombers	1600		6000	9372	8720

NOTE: The actual number of B-1B bombers in the inventory as of 1 June 1990 was 97. In our calculations we assumed 100.

Table A.4

**MODERNIZED SOVIET STRATEGIC OFFENSIVE FORCE STRUCTURE
CONSTRAINED BY START**

Force	Number	RVs per Missile	Total RVs	RVs On Line
ICBMs				
SS-18FO	154	10	1540	1540
SS-24 (rail)	112	10	1120	1120
SS-25 (road)	344	1	344	344
Total	610		3004	3004
SLBMs				
SS-N-20	100	10	1000	800
SS-N-23	224	4	896	832
Total	324		1896	1632
Total ballistic missiles	934		4900	4636
<hr/>				
		Weapons per Bomber	Total Counted	Total Actual
		Counted/Actual	Weapons	Weapons
<hr/>				
Bombers				
Bear H/ALCM	75	12/12	900	900
Blackjack	200	1/16	200	3200
Total	275		1100	4100
Total missiles and bombers	1209		6000	9000
				8332

Table A.5

**PERCENTAGE OF U.S. AND SOVIET FORCES CONSIDERED
NONTARGETABLE FOR THREE POSTULATED
OFFENSIVE FORCE POSTURES**

Forces	Posture A	Posture B	Posture C
United States			
SSBNs	60	75	90
Bombers	30	60	90
MX (rail)	0	50	100
Soviet Union			
SSBNs	30	60	90
Bombers	0	50	90
SS-24 (rail)	25	50	100
SS-25 (road)	25	50	100

Appendix B

ALTERNATIVE MODES FOR OPERATING STRATEGIC DEFENSES

In conducting the calculations for this study, we maintain that each nation operates its strategic nationwide ballistic missile defenses in a random subtractive mode—i.e., the defenses subtract RVs randomly out of an attack regardless of their type or destination. This appendix provides the analysis for choosing this mode over other modes for operating U.S. and Soviet boost-phase defenses.

To a first-order approximation, we suspect that enabling the defender to preferentially defend either retaliatory forces or value rather than operating in a random subtractive mode would have only a marginal effect on cost. Cost is a measure of the damage one incurs plus the damage one does not inflict discounted by some factor. Protecting one's own value decreases the first term but increases the second term. Alternatively, protecting retaliatory forces to inflict damage on the adversary's value decreases the second term but increases the first term. Preferentially protecting value or retaliatory forces is apt to have only a marginal effect on the total cost.

One way of treating this issue more methodically is to assume that the defender has certain options. We postulate that after detecting the launch, the defender can distinguish ballistic missiles carrying weapons with hard-target-kill capability from those without that capability, but he cannot determine the attacker's total attack option (whether these missiles are directed at value or silos and, in turn, his countersilo strategy, or how many hard-target-killers (HTKs) are attacking each silo).

The defender can intercept RVs in boost phase according to one of three defense modes:

1. Preferentially intercept RVs that have the potential to kill silos (HTKs).
2. Preferentially intercept RVs that do not have the capability to kill silos (non-HTKs).
3. Randomly subtract RVs from the total attack regardless of type.

Specifically, we assume that U.S. defenses could discriminate the highly accurate SS-18 and SS-19 RVs able to destroy hardened silos from RVs borne by other missiles that are effective only against such

soft targets as naval ports, army garrisons, airbases, and ammunition depots. If the United States operated its strategic nationwide BMD to preferentially intercept SS-18s and SS-19s, it would, in effect, preferentially defend its silo-based ICBM force. Conversely, if the United States operated its strategic defenses to preferentially intercept other Soviet missiles, it would, in effect, preferentially defend its value structure.

Figure B.1 depicts U.S. and Soviet costs as a function of alternative Soviet countersilo strategies, given the three defense modes described above.¹ U.S. and Soviet defense potential is set at 1500. Using the cost function established in Sec. II, we can determine the mode in which the United States would probably operate its defenses.

We assume that the Soviets orchestrate their first strike without knowledge of the mode in which U.S. defenses are to be operated. If they used all 5000 HTKs (SS-18 and SS-19 RVs) against U.S. silos, 4000 RVs (all non-HTKs) would be available to attack U.S. value. The Soviets might attack the first 1000 DGZs with 3000 of the available RVs and the second 1000 DGZs with 1000.²

The Soviets, however, might choose to attack U.S. silos more lightly, thereby releasing weapons for use against U.S. value. If they attacked U.S. silos with only 4000 HTKs, they would have 5000 RVs available to attack U.S. value and could allocate 3000 available RVs against the first 1000 U.S. DGZs and 2000 RVs against the second 1000 DGZs.

Figure B.1 demonstrates that such targeting strategies that concentrate on the highest-value U.S. targets prevent Soviet costs from shifting radically. This ensures that no Soviet attack "fails" catastrophically as far as the USSR is concerned. As expected, the lines representing the various U.S. defense modes parallel each other rather closely, both as a function of U.S. and of Soviet cost.

The defender chooses his defense mode on the basis of "least regrets." In other words, because he is unaware of the attacker's countersilo strategy, the defender attempts to cut his losses through options that minimize his highest cost. In the case displayed in Fig. B.1 (see the rightmost chart), the United States might choose the random subtractive mode because doing so ensures that its cost can be no higher than 0.89 regardless of the Soviet countersilo strategy.

¹Since the retaliator targets all of his RVs on the first-striker's value, the first-striker (in this case, the USSR) operates his defenses in a random subtractive mode.

²The USSR currently fields about 4400 on-line RVs with only soft-target-kill capability. When U.S. defense potential equals 1500, we assume that 400 of these Soviet RVs are allocated against U.S. SSBNs in port and nonalert bombers at their bases (also soft targets) to compensate for the reduction in P_p . Some 4000 RVs remain with which to attack U.S. value.

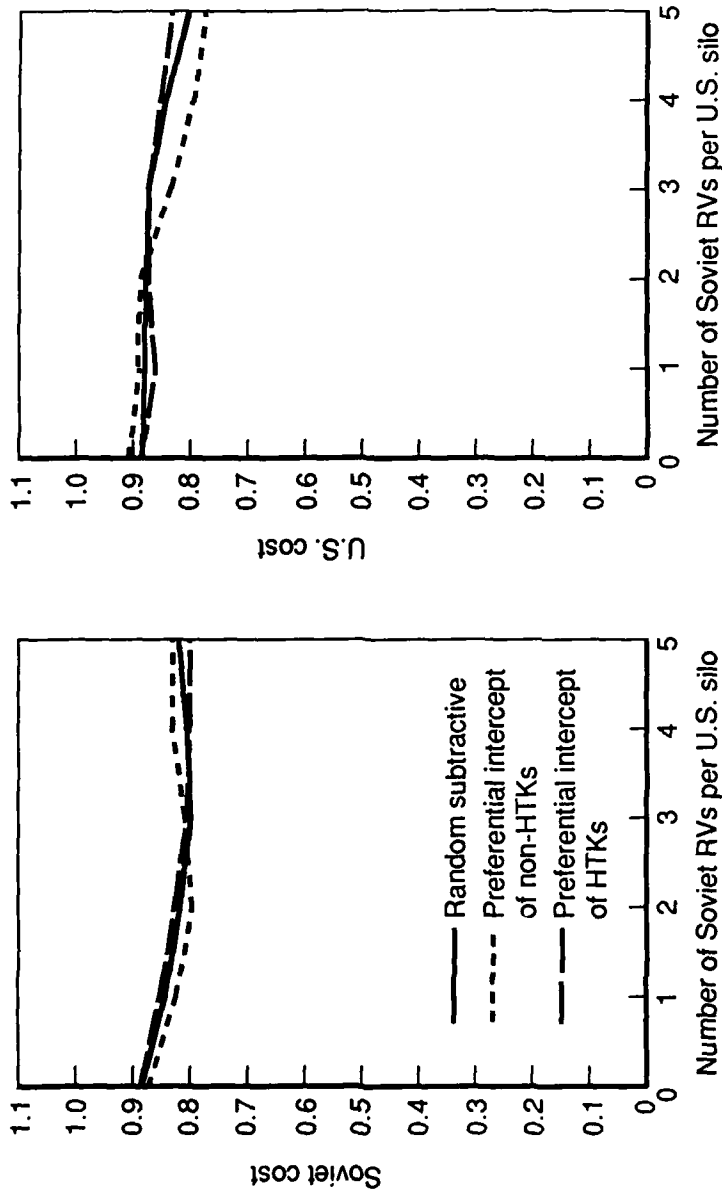


Fig. B.1—U.S. and Soviet costs as functions of alternative Soviet countersilo strategies for three U.S. defense modes—
U.S. and Soviet defense potential = 1500

Figure B.2 demonstrates the same variables when U.S. and Soviet defense potential reaches 4000. Again, the United States would probably choose to operate its defenses in a random subtractive mode to prevent its cost from exceeding 1.01. Choosing to preferentially intercept either HTKs or non-HTKs could potentially yield higher costs for the United States.

We conclude that (1) the random subtractive mode is likely to be preferred for operating boost-phase defenses, and (2) choosing one of the other modes has only a marginal effect on cost anyway. We therefore use the random subtractive mode in our calculations.

As a final observation, the results displayed in Figs. B.1 and B.2 suggest that if a U.S. leader were indeed faced with a Soviet first strike, and he believed that at least three Soviet RVs would be allocated to each U.S. silo, he would choose to preferentially defend U.S. value rather than U.S. retaliatory forces. He would rather limit damage to U.S. value than preserve the capability to inflict additional damage on the USSR in retaliation.

This preference follows the general rule that, given a choice, the defender minimizes his cost by preferentially defending those targets that are most lightly attacked. Thus, if the Soviets attack U.S. silos rather heavily, the United States operates its defenses most effectively by preferentially defending value.

The implication of these results is important. Part of the announced function of the "Phase I" deployment of U.S. strategic defenses (as dictated by the Joint Chiefs of Staff) is to subtract a given number of SS-18 RVs from a Soviet first strike and, by implication, to defend U.S. silos.³ Our analysis demonstrates, however, that a U.S. leader would not preferentially intercept RVs capable of destroying silos in an actual Soviet first strike. He would direct the defense to preferentially intercept RVs capable of damaging only soft targets, since defending value would minimize the U.S. cost of the war. Even if U.S. leaders declared a policy of defending silos in a Soviet first strike, the Soviets would not necessarily believe it. Instead, they might assume that U.S. leaders would emphasize limiting damage in a strategic nuclear war should it occur.

³See speech by Secretary of Defense Dick Cheney at the National Press Club, Washington, D.C., March 22, 1990.

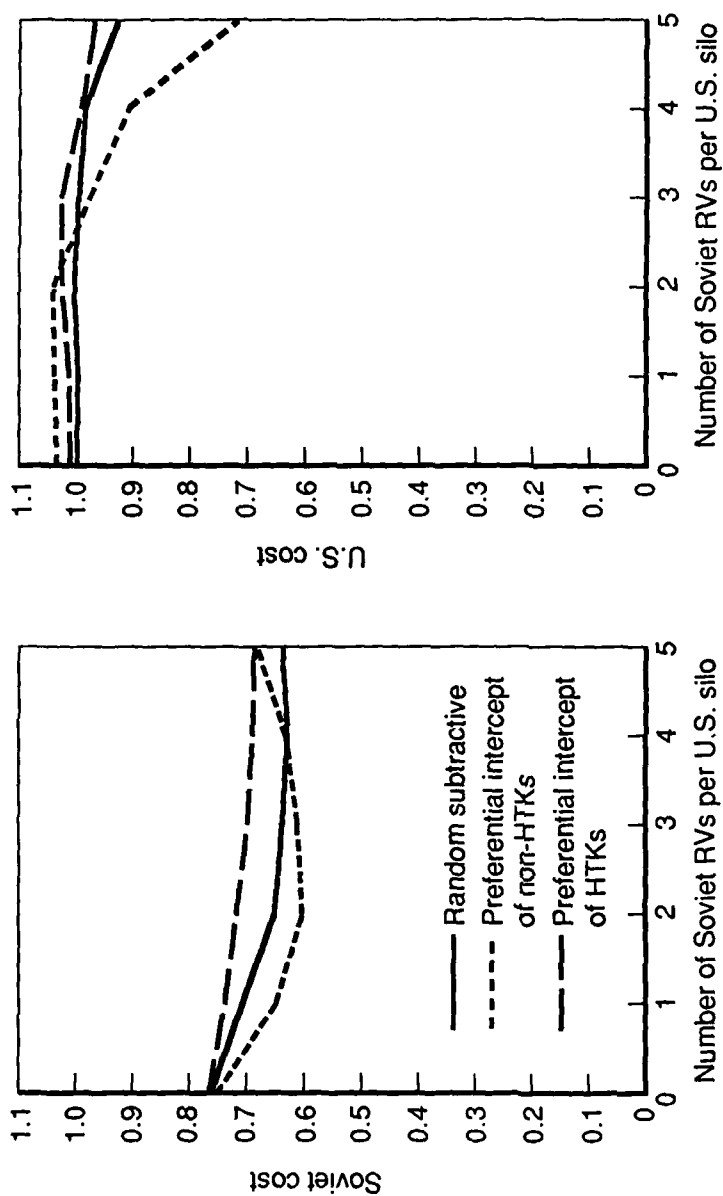


Fig. B.2—U.S. and Soviet costs as functions of alternative Soviet countersilo strategies for three U.S. defense modes—
U.S. and Soviet defense potential = 4000

Appendix C

TRANSLATING WEAPONS AVAILABLE INTO DAMAGE TO VALUE

To translate weapons available to attack value in the presence of defenses into the potential damage to that value, we create a series of cross-plots (Figs. C.1 and C.2), which we use to calculate the loci of endpoints (Figs. 5 and 6 in Sec. IV) and to draw curves that relate value damaged to defense potential (Figs. 8 and 9 in Sec. IV).

For a given structure and posture of U.S. and Soviet strategic offensive forces, we must create cross-plots for potential damage to:

- U.S. value in a Soviet first strike.
- U.S. value following a U.S. first strike.
- Soviet value in a U.S. first strike.
- Soviet value following a Soviet first strike.

The cross-plots in this appendix reflect current U.S. and Soviet strategic offensive forces where a Soviet first strike catches U.S. forces in posture B; U.S. and Soviet strategic defenses are operated in a random subtractive mode according to the analysis in App. B.

Figure C.1 shows the potential damage to U.S. value from a Soviet first strike as a function of the probability of penetration of Soviet RVs for various levels of Soviet RVs available to attack U.S. value. Each curve in Fig. C.1 represents a given number of Soviet RVs available to attack U.S. value—i.e., total on-line Soviet RVs less those used for counterforce. To draw the curve representing 2000 available Soviet RVs, for example, we calculate damage to U.S. value inflicted by 2000 Soviet RVs and 900 bomber weapons at each probability of RV penetration according to the process outlined in Sec. III (see "Relating Three Factors: Number of Attacking Weapons, Defense Potential, and Expected Damage to Value"). In these calculations, we assume a reliability of 0.85.

We repeat this process for various numbers of available Soviet RVs to create the family of curves. As can be seen, we postulate that 900 Soviet bomber weapons potentially could damage 35 percent of U.S.

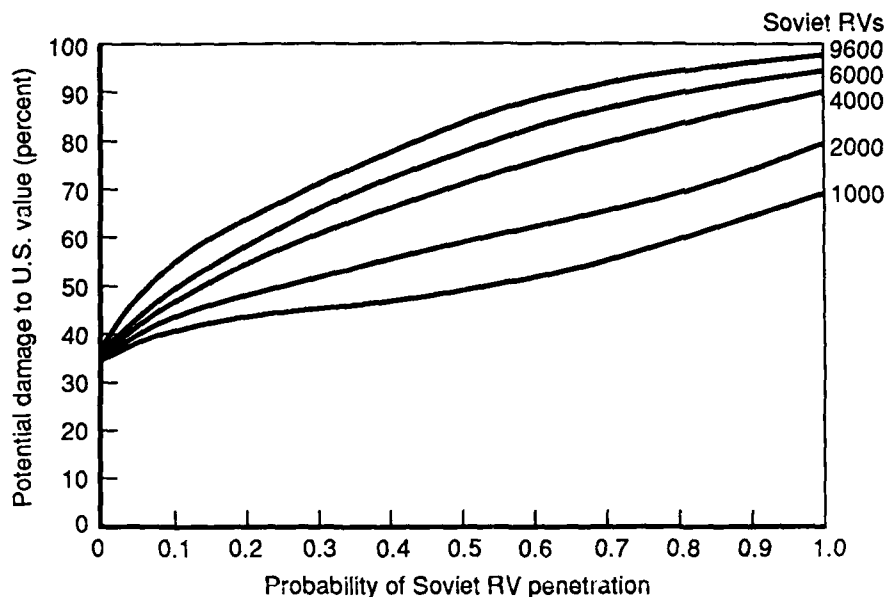


Fig. C.1—U.S. value damaged as a function of probability of Soviet RV penetration—Soviet first strike (current offensive forces, posture B)

value in a Soviet first strike when no Soviet RVs penetrate U.S. defenses (or when no Soviet RVs are available).¹

Using the data in Fig. C.1, we draw a cross-plot (Fig. C.2) that relates U.S. value damaged to the number of Soviet RVs available to attack U.S. value for various probabilities of Soviet RV penetration.

Figure C.2 offers the data in a form that, in conjunction with a similar cross-plot depicting Soviet value damaged in a U.S. retaliatory strike, can be used to evaluate alternative Soviet counterforce strategies and then to draw the loci of endpoints in Fig. 5 (Sec. IV). Figure C.2 also represents an intermediate step in the process of drawing curves that relate value damaged to defense potential, introduced in Figs. 8 and 9.

¹See the discussion in Sec. III on incorporating bombers into the methodology.

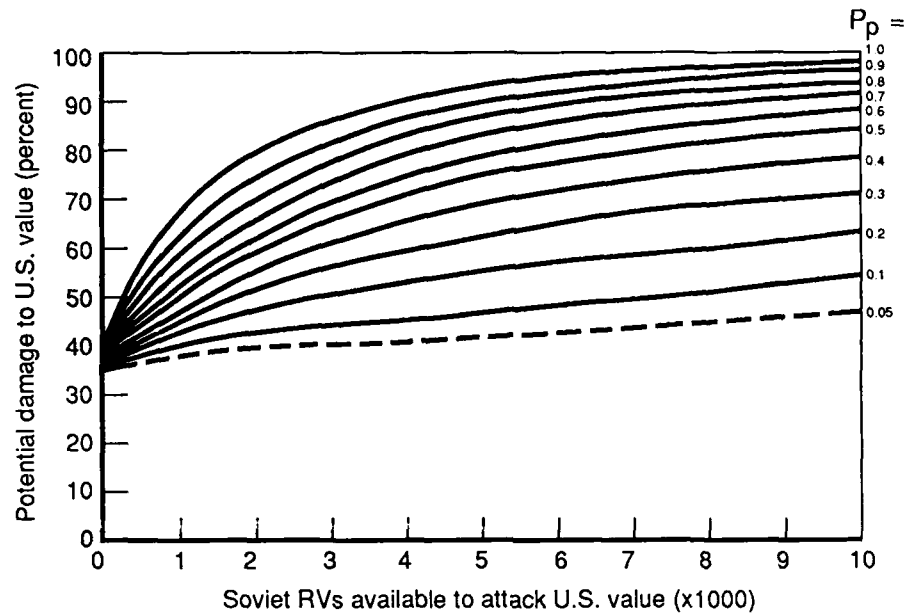


Fig. C.2—U.S. value damaged as a function of the number of Soviet RVs available to attack U.S. value—Soviet first strike (current offensive forces, posture B)

Appendix D

AN EXCURSION: ALTERING BOMBER ASSUMPTIONS

This study emphasizes the importance of capable bomber forces in preventing first-strike instability from becoming acute when each side deploys ballistic missile defenses at levels that overwhelm the enemy's retaliatory attack, but not his first strike. In Fig. 14 (Sec. IV), we find that the lowest values of the first-strike stability index in the defense domain approach 0.40. These values are lower than when defenses are absent, but hardly low enough to indicate what could be termed "acute" first-strike instability. Values much lower than 0.40 do not appear owing to the considerable damage bombers can inflict in a second strike even when the number of the retaliator's RVs penetrating the defenses is low.

We demonstrate in this appendix how first-strike stability is affected if we assume that the leaders of both nations believe that the Soviets can deny tactical warning to U.S. bombers. In such a situation, the USSR hopes and the United States fears that if the Soviets strike first, all U.S. bombers are destroyed, leaving only surviving U.S. ballistic missile RVs with which to attack Soviet value.

In Fig. D.1, we examine how the lack of tactical warning for U.S. bombers influences the stability index throughout the defense domain. We do this for current offensive forces operating in posture B.

In the lower left corner of Fig. D.1, representing a condition under which strategic defenses are absent, the stability index is fairly high. Because U.S. bombers and silo-based ICBMs are destroyed when no U.S. defenses are deployed, U.S. retaliatory capability rests on weapons aboard submarines at sea. Since these weapons are numerous (totaling some 3900 in posture B) and, neglecting reliability, have a 100 percent chance of penetrating to their targets, devastating U.S. retaliatory capability is ensured.

As each side deploys defenses against ballistic missiles, the values of the stability index quickly diminish. However, they diminish more dramatically along the Soviet axis (representing unilateral Soviet BMD deployments) than along the U.S. axis (representing unilateral U.S. BMD deployments).

Moving along the Soviet axis from a U.S./Soviet defense potential of 0/0 to about 0/4000, we find steep gradients between the isolines of

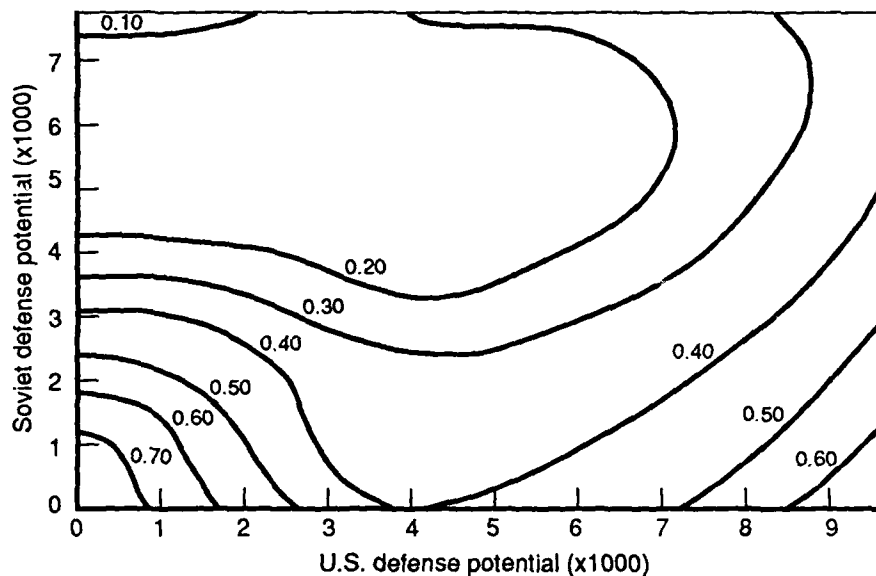


Fig. D.1—Isolines of constant values of the stability index in the defense domain—perception that Soviets can deny tactical warning to U.S. bombers (current offensive forces, posture B)

constant values of the index; i.e., the index quickly diminishes from nearly 0.80 to about 0.20 primarily because the Soviets attain the capability to limit damage substantially by striking first and removing U.S. bombers from the U.S. retaliatory attack and destroying the RVs from U.S. SLBMs at sea with their nationwide defenses. Conversely, if the Soviets waited and incurred a U.S. first strike, U.S. bombers could cause substantial damage to Soviet value. Thus, the cost to the USSR of going second greatly exceeds its cost of going first, which makes the ratio of Soviet costs low; and by definition, the index becomes low.

Figure D.2 relates Soviet value damaged to Soviet defense potential when U.S. defense potential is zero. It demonstrates that the reduction in the stability index along the Soviet axis is driven to a large degree by the Soviet ability to limit damage in first strike. Soviet damage from a U.S. retaliation (the solid line) falls precipitously compared with damage incurred from a U.S. first strike. The breakpoint on the solid line appears at a Soviet defense potential of about 4000,

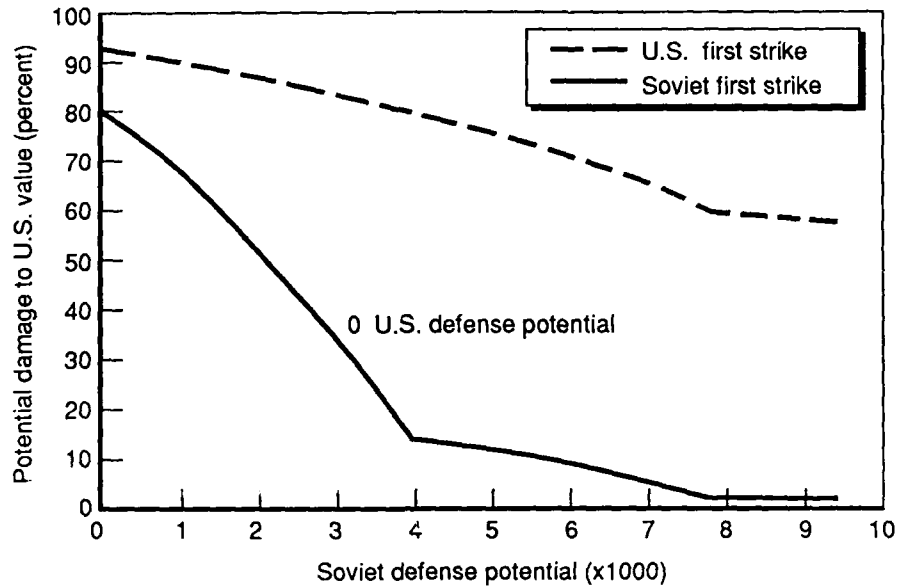


Fig. D.2—Potential damage to Soviet value as a function of Soviet defense potential—perception that Soviets can deny tactical warning to U.S. bombers (current offensive forces, posture B)

approximating the number of U.S. SLBM RVs that are at sea in posture B.¹ Just as the line depicting Soviet damage from a U.S. retaliation is steep up to this breakpoint, so too are the gradients between the isolines in Fig. D.1 up to a Soviet defense potential of about 4000.

Furthermore, the values of the index maintain a downward trend as the USSR deploys more robust defenses. This trend is derived from the fact that the USSR can begin to limit damage further through two-on-one intercepts of retaliating U.S. RVs.

The gradient in this area, however, is less steep. We can explain this by referring again to Fig. D.2, which shows that when Soviet defense potential extends beyond the 4000 retaliating U.S. RVs, the solid line slopes downward only gradually as the leak rate is reduced.

In summary, the perception that each side possesses capable bomber forces is instrumental in preventing first-strike instability from

¹We calculate that some 50 weapons atop U.S. ICBMs would also survive a Soviet first strike when the United States lacks strategic defenses.

becoming acute if each country deploys strategic nationwide ballistic missile defenses. Even when ballistic missile defenses can overwhelm a given RV attack, the defender is unable to limit his damage below a threshold maintained by the attacker's bombers. However, if either side can eliminate this threshold in a first strike by negating the opponent's bomber forces, acute first-strike instability arises.